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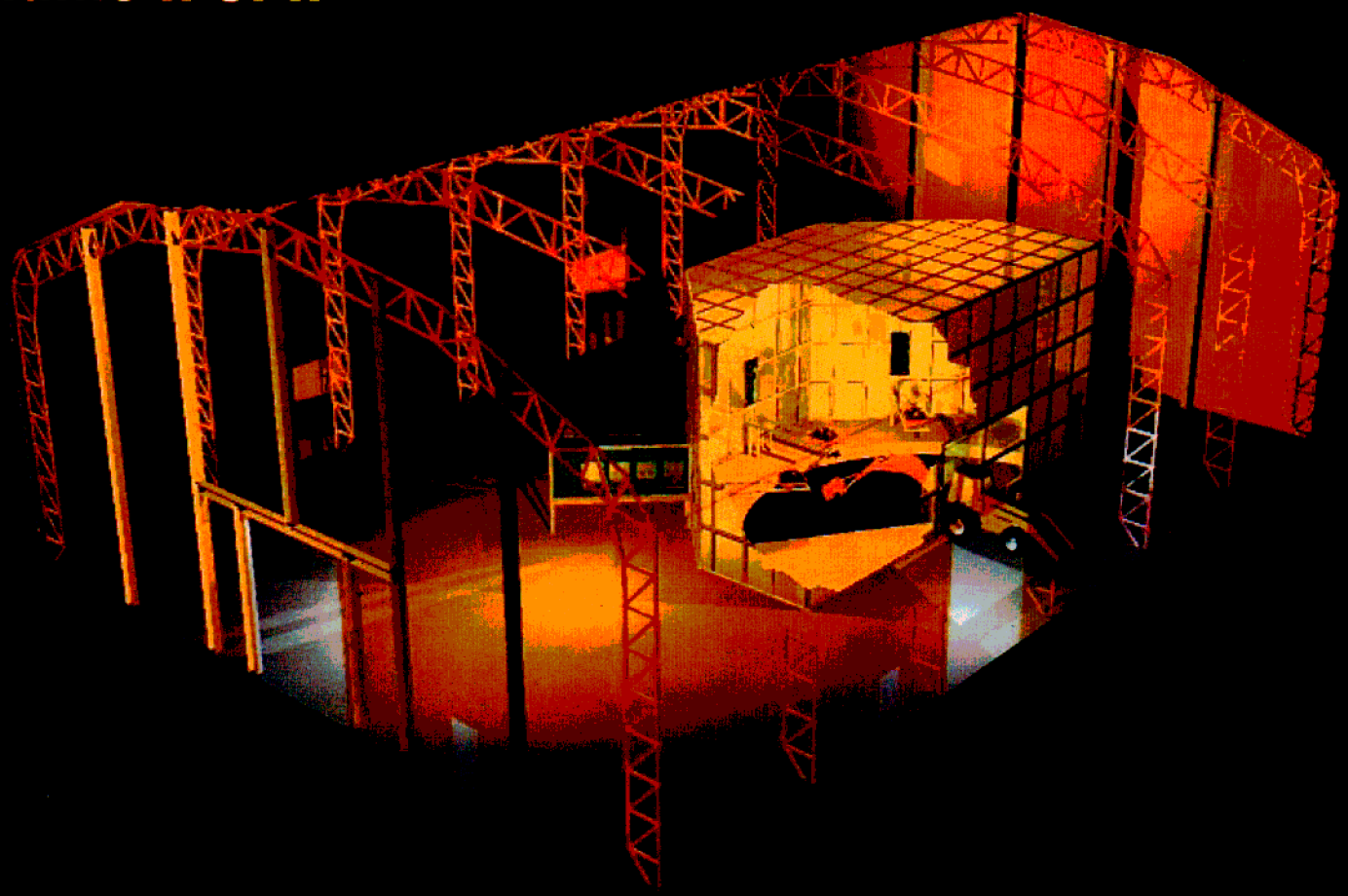
U.S. Department of Energ
Idaho Operations Offic

Remedial Design Package for the OU 7-10 Glovebox Excavator Method Project

Volume II of II



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7. Additional Required Studies

Section 7 contains selected documents that are provided as additional required studies and that satisfy the following required remedial design elements:

- Process volume, flow rates, and quantities
- Process flow diagrams
- ARARs, to be considered guidance, and permitting considerations
- Sampling and analysis plan.

7.1 Air Emissions

Sections 7.1.1 and 7.1.2 contain documents relating to project air emissions including the project Air Emissions Evaluation and the National Emission Standards for Hazardous Air Pollutants (NESHAPs) radiological monitoring plan. These documents are provided as additional required studies.

7.1.1 Air Emissions Evaluation

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Effective Date: 9/12/2002

Engineering Design File

PROJECT FILE NO. 021052

Air Emissions Evaluation for the OU 7-10 Glovebox Excavator Method Project

Prepared for:
U.S. Department of Energy
Idaho Operations Office
Idaho Falls, Idaho

Idaho National Engineering and Environmental Laboratory

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ENGINEERING DESIGN FILE

1. Title: Air Emissions Evaluation for the OU 7-10 Glovebox Excavator Method Project

2. Project File No.: 021052

3. Index Codes:
   Building/Type NA SSC ID N/A Site Area 098

4. Summary: This engineering design file presents a revised evaluation of the radiological and toxic air pollutant atmospheric emissions of the planned Operable Unit (OU) 7-10 Glovebox Excavator Method Project. Operable Unit 7-10 comprises Pit 9 within the Radioactive Waste Management Complex at the Idaho National Engineering and Environmental Laboratory. This revision incorporates project and engineering design changes for the retrieval project as of July 1, 2002. The identified changes that affect the air emissions calculations include the following:

- Decreased excavated waste volume
- Decreased operational period
- Increased daily retrieval rate
- Increased surface area of exposed pit walls
- Increased airflow over waste in the gloveboxes
- Increased diesel exhaust emissions from a backhoe excavator in addition to a diesel generator.

Results: Modeling results indicate that maximum impacts at Idaho National Engineering and Environmental Laboratory boundary locations, U.S. public highways, Experimental Breeder Reactor I, and Radioactive Waste Management Complex worker locations will be less than the applicable U.S. Environmental Protection Agency, State of Idaho, and Occupational Safety and Health Administration standards. Compared to the previously calculated impacts for the Stage II project, the current design produces the impacts listed below:

- Forty percent lower maximum radiological dose and cancer risk, which are still significantly less than all dose criteria
- Unabated dose impacts that still exceed the National Emission Standard for Hazardous Air Pollutants monitoring criteria (0.1 mrem/year) for Pu-239 and Am-241 only
- Fifty percent higher nonradiological impacts (hazard indices and cancer risk), which are still less than applicable toxic air pollutant standards and U.S. Environmental Protection Agency risk criteria (1E-04 to 1E-06).

Most of the decreases are caused by the significant reduction in planned operating time (and thus emissions time and total contaminant mass released) for this project (90 days or less) compared to the previous Stage II project (1 year).

5. Review (R) and Approval (A) and Acceptance (Ac) Signatures:
   (See instructions for definitions of terms and significance of signatures.)

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   Electronic copy distribution to OU 7-10 Glovebox Excavator Method Records Management (MS 3920, snarrll@inel.gov).

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ACRONYMS

AAC	ambient air concentrations
AACC	ambient concentrations for carcinogens
CFA	Central Facilities Area
DF	decontamination factor
EBR-I	Experimental Breeder Reactor I
EPA	U.S. Environmental Protection Agency
HEPA	high-efficiency particulate air
IAAQS	Idaho Ambient Air Quality Standards
IDAPA	Idaho Administrative Procedures Act
INEEL	Idaho National Engineering and Environmental Laboratory
MEI	maximally exposed individual
NAAQS	National Ambient Air Quality Standards
NESHAPS	National Emission Standard for Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
OEL	occupational exposure limit
OU	operable unit
PGS	Packaging Glovebox System
RCS	Retrieval Confinement Structure
RF	respirable fraction
RWMC	Radioactive Waste Management Complex
TAP	toxic air pollutant
TRU	transuranic
VOC	volatile organic compounds

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Air Emissions Evaluation for the OU 7-10 Glovebox Excavator Method Project

1. INTRODUCTION

This air emissions evaluation provides calculations that predict maximum radionuclide and toxic chemical atmospheric emission rates and downwind impacts (i.e., dose and risk) from the Operable Unit (OU) 7-10 Glovebox Excavator Method Project (INEEL 2002). The objective of this U.S. Department of Energy project is to demonstrate the safe retrieval of transuranic (TRU) waste from a specific, preselected area of OU 7-10 (which comprises Pit 9) in the Subsurface Disposal Area within the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering and Environmental Laboratory (INEEL). The project will use a commercial excavator, operated from outside a confinement structure, to remove waste inside the structure. The waste will be placed in carts and transported to gloveboxes connected to the confinement structure where personnel can safely inspect, characterize, and package excavated material.

The objectives of this air emissions evaluation include the following:

1. Estimate conservative radionuclide, toxic air pollutant (TAP) and criteria pollutant atmospheric emission rates from excavation and glovebox containment (out of the facility vent) during the operational period of the project. Accident releases were not evaluated.

2. Perform a downwind dose and risk assessment for these emissions using the U.S. Environmental Protection Agency (EPA) CAP-88 dose assessment model and radionuclide slope factors (EPA 2002) to (a) demonstrate compliance with 40 CFR 61, "National Emission Standard for Hazardous Air Pollutants," (NESHAP) (i.e., 10 mrem/year dose standard for abated emissions and 0.1 mrem/year emissions monitoring criteria for unabated emissions) and (b) estimate the maximum incremental risk of cancer incidence to the public and to a worker at the RWMC. Two receptors were evaluated: (a) a hypothetical maximally exposed individual (MEI) member of the public who is assumed to reside at the Site boundary location of maximum downwind exposure, and (b) an RWMC worker located immediately downwind of the glovebox facility vent (or any potential release point at the facility).

3. Perform air dispersion modeling for TAP and criteria pollutant emissions to determine appropriate time-averaged maximum ambient air concentrations at public access receptor locations specified in the "Rules for the Control of Air Pollution in Idaho" (IDAPA 58.01.01.210) and for an RWMC worker. Compare maximum ambient air concentrations to State of Idaho TAP screening increments given in Idaho Administrative Procedures Act (IDAPA) 58.01.01.585-586 and the Idaho and National Ambient Air Quality Standards (IAAQS/NAAQS). Compare the RWMC worker exposure to threshold limit values as established by the American Conference of Governmental Industrial Hygienists. For TAPs, calculate maximum short-term health impacts (i.e., cancer risks and hazard indices) for members of the public at the public access location with the highest air concentrations (Experimental Breeder Reactor I [EBR-I]) and the maximally exposed RWMC worker.

A complete description of the proposed project is given in the *OU 7-10 Glovebox Method Excavator Project, Conceptual Design Report for Critical Decision 1* (INEEL 2002). The emissions evaluated in this assessment include suspended particulate and volatile organic compound (VOC) emissions that could occur from the two primary containment sources in the area of operations (see Figure 1): (1) the Retrieval Confinement Structure (RCS), which encloses the excavation area, and (2) the

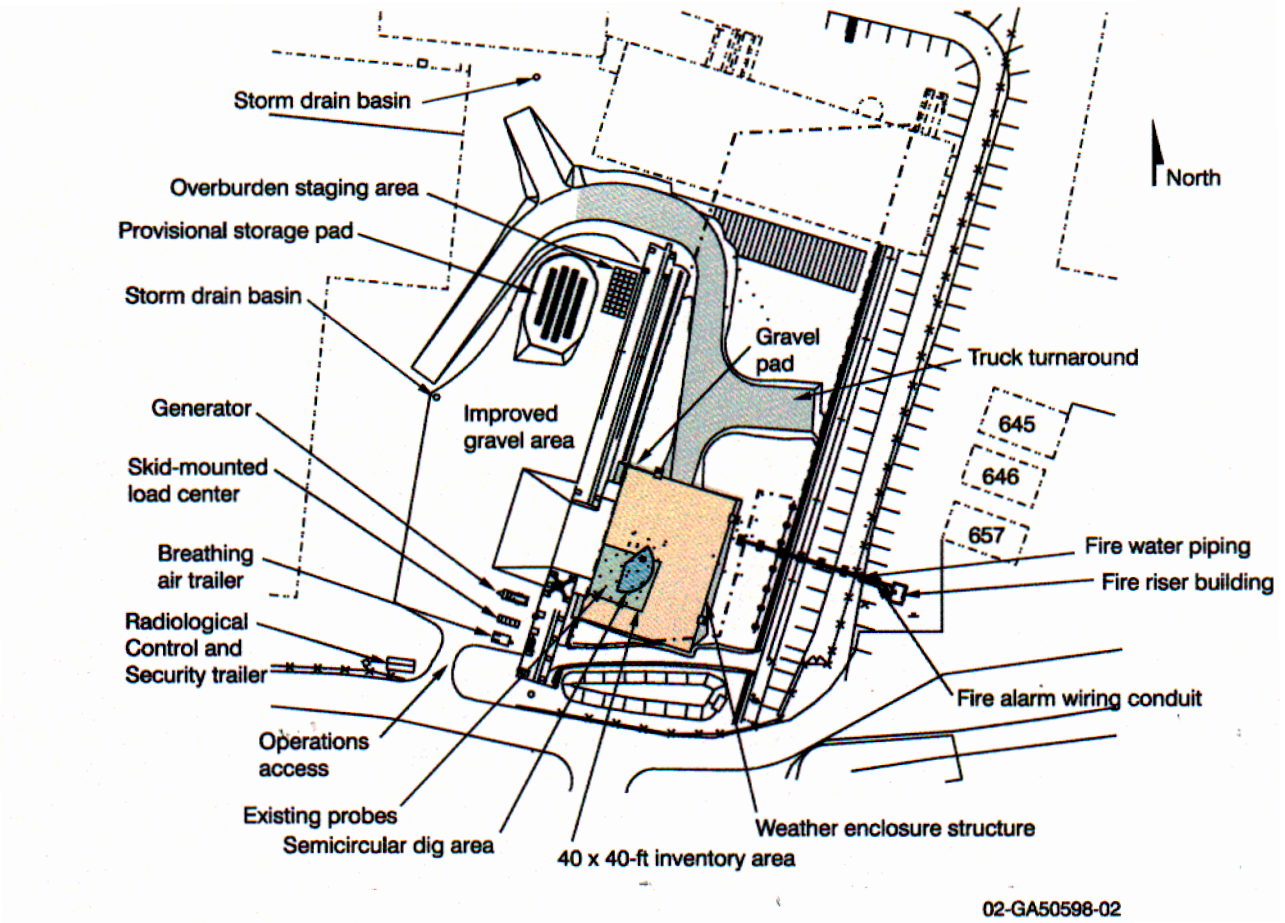

Figure 1. Detailed plot of the existing OU 7-10 area showing planned excavation area.

Packaging Glovebox System (PGS), where the waste is segregated, sampled, and packaged. A detailed view of the project is shown in Figure 2. Also evaluated are potential emissions from drum storage and diesel exhaust from the backhoe excavator and an emergency diesel generator.

This revision of the air emissions evaluation modifies previous calculations made in the *Stage II Air Emissions Evaluation* (Abbott 2000) made for the OU 7-10 Stage II Interim Action Project (INEEL 1998) to account for the following most recent operational design parameter changes:[a]

1. **Excavated waste volume decreased to 57 m^3 (75 yd^3), from the previously assumed Stage II** volume of 91 m^3 (119 yd^3) (20 × 20 × 8-ft deep waste zone). A smaller volume increases the maximum possible radionuclide concentration in the excavated waste by decreasing the number of lower activity drums that could fit into this space. Note: The method assumes the excavation volume is filled with the highest activity drums first because the exact breakdown of drums in the excavation volume is unknown (see Section 2.4).

a. Stephanie Walsh E-mail to Michael L. Abbott, "Operational Design Parameter Changes," INEEL, March 6, 2002.

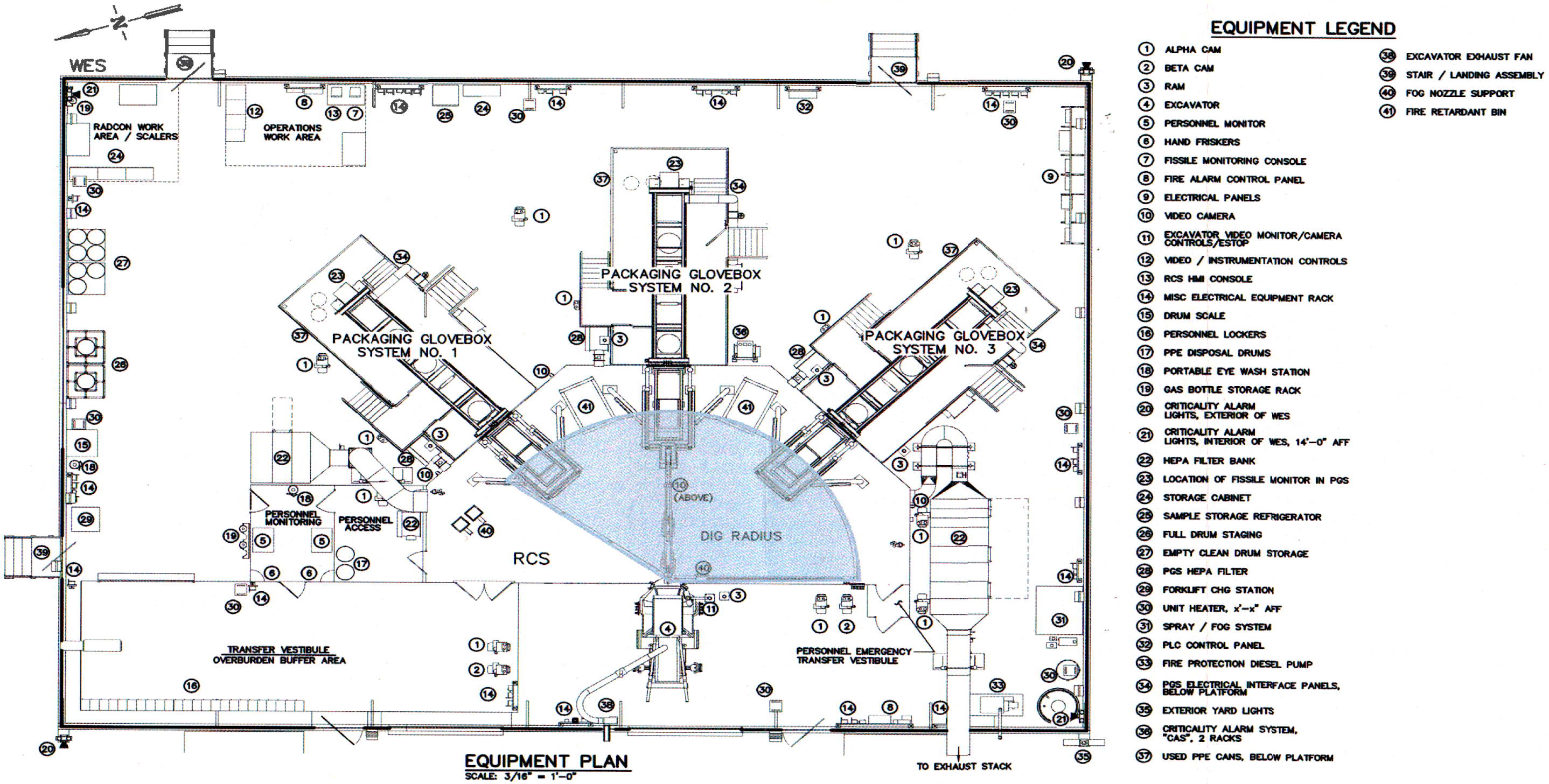

Figure 2. The Packaging Glovebox System showing the three rectangular gloveboxes attached in fan fashion to the Retrieval Confinement Structure.

2. Operational period for excavation decreased from the previously assumed time of approximately 1 year to 1 to 3 months. A shorter time period decreases the calculated annual average emission rates of contaminants (used to assess carcinogenic impacts) and also reduces the amount of time for VOC emissions through digface diffusion.

3. Daily retrieval rate of soil and waste was changed to 0.53 to 1.8 m^3 per day (19 to 64 ft^3 per day), from the previously assumed rate of 0.75 m^3 per day (26.5 ft^3 per day). A higher rate increases the short-term time-averaged VOC emission rate from excavated soil.

4. Surface area of exposed pit walls and bottom (waste area only) increased to 70.4 m^2 (758 ft^2) from the previously assumed area of 2.3 m^2 (80 ft^2) (assumed area not covered by sheet pile). A larger area increases the VOC emission rate from undisturbed waste exposed at the digface wall.

5. Airflow over waste in the PGS increased to 396 cm/minute (12.9 ft/minute), from the previously assumed material handling cell rate of 168 cm/minute (5.5 ft/minute). A higher airflow rate over the waste increases the VOC emission rates through the vaporization pathway.

6. The area of exposed waste in the PGS was reduced to 2.5 m^2 (26.9 ft^2) (32 × 42-in. cart × three gloveboxes), from the previously assumed material handling cell table area of 3.3 m^2 (35.5 ft^2). A smaller area decreases the VOC emission rates through the vaporization pathway.

7. Diesel operations changed to 282 kW and 520 hours/month for a new diesel backhoe excavator (110 hp/82 kW, 17 hours per day continuous operations) and emergency diesel generator (200 kW, 10 hours/month), from the previous assumption of a 400-kW diesel generator only operating for 4 hours/month. These changes resulted in an overall increase in the emission rates of criteria pollutants (i.e., NO_2, SO_2, CO, and PM_{10}[b]).

The environmental dose assessment made here follows the general methods used in previous analyses done for the original OU 7-10 cleanup project (Staley 1992; 1993). However, several modifications and refinements of those methods were made to account for revised waste inventories (Smith and Kudera 1996; Thomas[c,d]) and improved or updated modeling and parameter estimation methods. Improved modeling and model parameterization included the use of a more recent 10-year meteorological input file, more appropriate dust-loading parameters, updated air dispersion models (SCREEN3 and ISC3), and the assessment of VOC emissions from four different mechanisms. These included (1) vapor releases from air-filled pore spaces in the excavated soil, (2) volatilization of VOCs in solution with soil water in the water-filled pore spaces of the excavated soil, (3) emissions of VOCs from undisturbed waste exposed at the digface walls, and (4) vapor releases from waste sludge exposed in the PGS.

It is important to note that this assessment was done for regulatory compliance purposes (i.e., to demonstrate with a reasonably high level of confidence using approved regulatory methods that

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b. Particles smaller than 2.5 μ are referred to as PM2.5. Larger particles up to 10 μ in diameter are designated PM10.

c. R. W. Thomas Interoffice Memorandum to D. E. Wilkins, October 14, 1999, "Pit 9 Inventory Data Supporting OU 7-10 Stage I Air Emissions Evaluation," RWT-07-99, INEEL, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.

d. R. W. Thomas Interoffice Memorandum to A. G. Ramos, April 27, 1999, "Waste Contents Information Supporting Unreviewed Safety Question (USQ) for OU 7-10 Stage II Storage Facility," RWT-02-99, INEEL, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.

maximum impacts will be less than radiological dose and TAP standards). As such, reasonably conservative methods or parameter values were used unless the parameter was well known. The use of conservative assumptions throughout the assessment provides a high degree of confidence that the calculated impacts will likely overestimate any actual impacts.

2. METHODS

2.1 Source Term Development

The vast majority of the effort in this assessment was toward development of a reasonably conservative but detailed source term, which includes the following:

- Identification of the contaminants (both radiological and nonradiological TAP) present in the waste
- A reasonable prediction of high-end contaminant concentrations that might be encountered during excavation
- Prediction of appropriate time-averaged stack (or vent) emission rates to the atmosphere.

The project team developed the source term using Microsoft Excel worksheets (Appendix A) that can be easily modified if parameter values need to be changed because of internal and agency review comments or if design changes are desired. The spreadsheets are organized by contaminant categories (e.g., radiological, nonradiological, nonvolatile, or volatile) that adequately explain and provide the basis for the detailed analysis methods and parameter values selected.

2.2 Assessment of the Radiological Source Term

The two independent methods used to estimate the radionuclide concentrations in the waste are listed below:

- **Method 1**—is a simplified method that was used in the original version of this assessment. It is based on the assumption that the entire OU 7-10 inventory as given in Smith and Kudera (1996) and King (1991) is uniformly distributed throughout a conservative fraction (one quarter) of the pit volume.
- **Method 2**—is a revised method that uses more recent estimates of actual waste types and numbers of drums that might be located in the excavation area as provided by Thomas (1999a; 1999b).

Although Method 2 is currently considered to be the best available information, both methods have an unknown level of uncertainty associated with them and are retained here for comparison. Reasonable agreement between the results of these two independent methods provides a degree of confidence in the calculations.

2.3 Method 1

The 1968 inventory given in Smith and Kudera (1996) and King (1991) for Co-60 and Cs-137 was decay- and ingrowth-corrected using Microshield 4.0 software[e] (see Table 1). One-hundred percent of the inventory was conservatively assumed to be located in the southern half of the pit (where the project excavation is planned) based on the locations of TRU waste drums given in *History of Buried Transuranic Waste at INEL* (EG&G 1977) (see Figure 3). This will double the concentration compared to uniformly distributing the inventory throughout the pit.

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e. Grove Engineering, 15215 Shady Grove Road, Rockville, Maryland 20850.

Table 1. Radionuclide inventory in OU 7-10 in 1968.[a]

Nuclide: Parent Progeny	Total OU 7-10 Activity 1968 (Ci)	Total OU 7-10 Activity 2001 (Ci)	Nuclide: Parent Progeny	Total OU 7-10 Activity 1968 (Ci)	Total OU 7-10 Activity 2001 (Ci)
Pu-238	5.0E+01	3.9E+01	U-238	1.5E+00	1.5E+00
Pu-239	1.7E+02	1.7E+03	Th-234	d	1.5E+00
Pu-240	3.9E+02	3.9E+02	Pa-234m	d	1.5E+00
U-236	d	3.8E-04	Pa-234	d	2.4E-03
Th-232	d	3.1E-13	Ra-226	2.1E-02	2.1E-02
Ra-228	d	1.9E-13	Rn-222	d	2.1E-02
Ac-228	d	1.9E-13	Po-218	d	2.1E-02
Pu-241	1.1E+0	2.2E+03	Pb-214	d	2.1E-02
Am-241	d	2.8E+02	Bi-214	d	2.1E-02
Np-237	d	1.9E-03	Po-214	d	2.1E-02
Pa-233	d	1.9E-03	Pb-210	d	1.3E-02
U-233	d	2.4E-06	Bi-210	d	1.3E-02
Th-229	d	2.5E-09	Po-210	d	1.3E-02
Am-241	3.2E+03	3.0E+03	H-3	1.9E-01	2.9E-02
Np-237	d	3.3E-02	C-14	1.9E-03	1.9E-03
Pa-233	d	3.3E-02	Fe-55	4.6E+02	9.6E-02
U-233	d	2.4E-06	Ni-59	3.3E-03	3.3E-03
Th-229	d	2.5E-09	Co-60	3.1E-01	4.0E-03
Pu-242	2.0E-02	2.0E-02	Ni-63	1.5E+02	1.2E+02
U-234	7.0E-01	7.0E-01	Sr-90	3.7E+01	1.7E+01
Th-230	d	2.1E-04	Y-90	d	1.7E+01
U-235	3.5E-02	3.5E-02	Tc-99	5.0E-04	5.0E-04
Th-231	d	3.5E-02	I-129	6.2E-07	6.2E-07
Pa-231	d	2.4E-05	Cs-137	4.5E+00	2.1E+00
Ac-227	d	9.3E-06	Ba-137m	d	2.0E+00
Th-227	d	9.1E-06			
Fr-223	d	1.3E-07			

a. The radionuclide inventory in OU 7-10 in 1968 was decay-corrected to the planned Stage II operations date of 2001 (the activity in 2002 will not be appreciably different). All 1968 inventory values are from Smith and Kudera (1996) except for Co-60 and Cs-137, which use the values from King (1991).

d = progeny

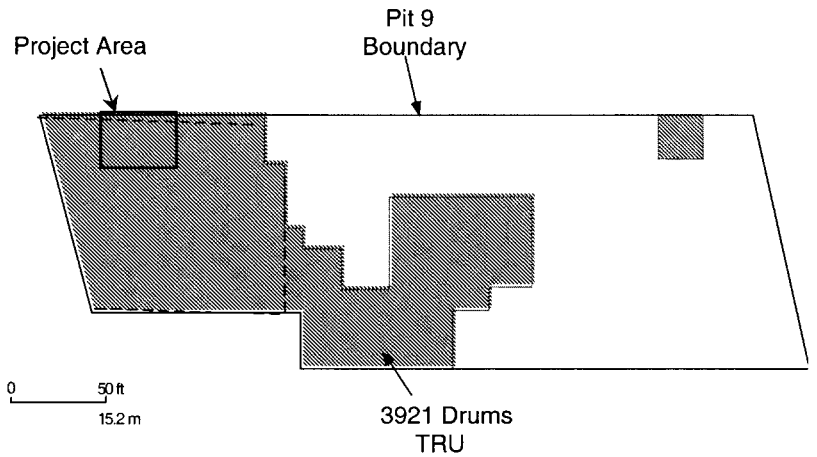

Figure 3. Location of transuranic waste drums disposed of in OU 7-10 (EG&G 1977) and the location of the OU 7-10 Glovebox Excavator Method Project area.

The equation developed in Method 1 to calculate the annual average stack emission rate for radionuclide i (E_i, in Ci/year) is shown in Equation (1).

$$E_i = \left(\frac{A_i}{V\ f_1}\right) f_2\ (1/\rho)\ D\ f_3\ RF\ F\ f_4\ (1/DF) \tag{1}$$

where

Ai	=	decay-corrected activity inventory for radionuclide i (Ci)
V	=	total (waste + soil) volume in OU 7-10 (21,240 m^3)
f_1	=	fraction of the pit that contains loaded TRU waste drums (0.5)
f_2	=	waste distribution uncertainty factor (2)
ρ	=	weighted average of waste plus soil density (1.2E+06 g/m^3)
D	=	dust loading factor (0.5 g/m^3)
f_3	=	dust-suppression factor (0.5)
RF	=	respirable activity fraction (0.4)
F	=	total ventilation flow rate for the facility (6,860 cfm, 1.2E+04 m^3/hour)
f_4	=	expected period of operations (2,160 hours/year [90 days continuous])
DF	=	combined decontamination factor for tested two-stage high-efficiency particulate air (HEPA) filters (9E+06).

For assessment of radionuclides and particulate carcinogenic TAPs, the inventories (A_i) were assumed to be mixed across all depths rather than just in the waste layer. This was done because dose and

carcinogenic risk are proportional to the annual integrated dose or air concentration, which requires an annual average release rate (e.g., Ci/year). Because the entire operation will be completed in less than 1 year, the appropriate annual average release rate can be obtained by mixing the estimated inventory in the total excavation volume (waste and overburden) and setting the release time equal to the time required to do the entire excavation (90 days). An alternative (but equivalent) method would be to mix the inventory only through the waste layer and release the contaminants only during the time period that the waste layer is being excavated (currently unknown). Both methods result in the same total activity (Ci) released and annual average (Ci/year) release rate.

The resulting activity concentration (Ci/g soil for each nuclide) is then multiplied by a waste distribution uncertainty factor (f_2) to account for the potential increase in the average activity concentration that might be encountered in the excavation volume (75 yd^3) compared to the pit volume (50% of the total) that was assumed to have all the inventory. A previous analysis[f] examined published statistical distributions of plutonium concentrations in Rocky Flats Plant aboveground waste (Atwood and Schlafman 1993) to estimate a 95%-to-average plutonium drum-loading ratio of 3. Although it is certainly possible that some of the excavated waste could be at the 95% concentration, it is unlikely that all of the waste will be greater than or equal to this high-end concentration. Therefore, a value of 2 was assumed for this parameter to provide a reasonable degree of conservatism. When combined with the 50% fraction of the pit assumed to have the entire waste inventory, a waste distribution uncertainty factor of 2 results in a factor of 4 higher activity concentration in the modeled excavation volume compared to an assumption of uniform inventory distribution throughout the pit.

The activity suspended within the RCS primary containment is assumed to be primarily attached to suspended soil. Therefore, suspension is calculated using a dust-loading factor (D) that is based on measured airborne dust concentrations for certain types of operations. The dust-loading factor used was 0.5 g/m^3, which is for very dusty conditions found near a mine working face with no dust suppression controls (NRC 1982). This is a conservative value for application within the RCS because of the relatively careful excavation method that is planned and because it does not account for low activity times where the dust suspension would be much lower. That is, the dust-loading factor is a short-term peak factor, which, if used over the entire year, will significantly overestimate the annual average concentration used for dose and risk calculations.

Suspended concentrations are reduced by factors of 0.5 to account for planned dust-suppression equipment (EPA 1995a) and 0.4 to account for the respirable (<10 μm) activity fraction (RF) (NRC 1982; Krey et al. 1976). The resulting concentration within containment is then multiplied by the annual average ventilation exhaust flow rate (6,860 cfm, converted to 11,700 m^3/hour) and the planned 90-day period of operations (2,160 hours/year). The results are divided by a decontamination factor (DF) for two HEPA filters in series (two-stage) that will be fully tested and maintained. For a given number of HEPA stages (n), *The Nuclear Air Cleaning Handbook* (ERDA 1976) recommends the following:

> For purposes of estimating the capability of a multistage HEPA filter installation under normal operating conditions, a DF of $(3 \times 10^3)^n$ can be safely used with systems that adhere to the design, construction, testability, and maintainability principles of this handbook or of ANSI N509[g].

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f. S. J. Bengston Letter to C. D. Gentillon, "Estimate of Variation in OU 7-10 Radionuclide Concentration—CDG 2-98," December 3, 1998, INEEL, LMITCO, Idaho Falls, Idaho.

g. ANSI N509, *Nuclear Power Plant Air Cleaning Units and Components*, American National Standards Institute, 1976.

This recommended DF (9E+06 for two stages [n = 2]) is based on several filter test results and corresponds to an individual filter efficiency of about 99.97%. This is the minimum filtration efficiency at which HEPA filters must be tested. Tests are conducted to confirm this before shipment of the filters to the INEEL, after installation of the filter, and at intervals of less than 1 year during use (if they are used that long).

2.4 Method 2

As an alternative to Method 1, inventory data provided by Einerson and Thomas (1999) and Thomas (see footnotes b and c) were evaluated. This information provided plutonium, Am-241, and organic constituent drum loadings and the number of drums with these loadings expected to be within a 40 × 40-ft potential area of operations based on disposal coordinates marked on the generator shipping records (manifests). Only Am-241 and the plutonium isotopes were addressed by Thomas, and are the only ones evaluated here because they account for more than 99.97% of the total dose from all radionuclides (see Section 2.3, "Method 1").

This method involved the following steps:

1. The total number of 55-gal (0.208 m^3 [0.272 yd^3]) drums expected to be located in the excavated waste volume was calculated. For the calculation, a smaller volume (50.2 m^3 [65.6 yd^3]) was assumed because it gives a more conservative estimate of waste concentration (see steps below). Previous retrieval operations involving dumped drums in Pit 10 (Thompson 1972) at the Subsurface Disposal Area determined that approximately 50% of the waste zone was filled with soil. Assuming drums occupy one-half (25.1 m^3 [32.8 yd^3]) of the waste zone, the minimum number of 55-gal drums expected in the waste zone is approximately 120.

2. Table 2: Using the Pu/Am-241 drum loading information in Thomas (footnotes b and c), a worst-case activity inventory that would fit into the Stage II waste zone was determined. This involved identifying the drums known to be in the area with the highest Pu/Am-241 loading, calculating the decay-corrected activity per drum, and then summing the activity for each of the drum waste types. To confirm that the drums with the highest Pu/Am-241 loading were also those that would result in the highest dose or risk impacts, an index was calculated for the dose-per-unit drum hazard. This hazard index was only used to rank drums in accordance with their relative hazard and was not used to calculate dose impacts from atmospheric emissions.

3. Table 3: The total activity in excavated waste zone volume was calculated by summing across the five worst-case waste types, starting with the waste types that would provide the highest dose or risk, until 120 drum inventories were included. The total excavated waste (drum) mass was calculated by multiplying each of the 120 drums by their respective waste type weights (less 75 lb for the drum, liner, and bagging) using the Rocky Flats Waste Type/Waste Code correlations in Thomas (footnote c) and the average drum weights given in the *Content Code Assessment s for the INEL Contact-Handled Stored Transuranic Wastes* (Clements 1982). The total soil mass in the excavated waste volume (3E+07 g) was calculated by multiplying 50% of the waste zone volume (2.5E+07 cm^3 [32.8 yd^3]) by an assumed soil density of 1.2 g/cm^3. The total suspendable mass was calculated by adding the calculated waste and soil masses in the excavated waste volume.

4. Table 4: Radionuclide concentrations for the suspendable waste mass (Ci/g) were calculated by dividing the Step 3 total excavated waste activity by the total suspendable mass in the waste zone. Unabated annual emission rates (Ci/year) then were calculated in the same manner as Equation (1) (Method 1). The activity concentrations in the suspendable waste zone mass (Ci/g) were multiplied by the factors listed in Table 4.

Table 2. Activity of the most hazardous waste in the excavation area.

Drum Type = 741 Sludge
Pu Grams/drum = 4.3

Isotope	Weapons Grade Fraction	Grams/ Drum	Specific Activity (Ci/g)	Activity (Ci/drum) 1970	Activity (Ci/drum) 2002	Activity Drums in Exc. Area (Ci)	MEI CAP-88 Unit Dose (mrem/Ci)	Dose/ Drum (mrem)
Pu-238	0.00012	5.2E-04	1.7E+01	8.8E-03	6.8E-03	2.0E-02	1.7E+01	1.1E-01
Pu-239	0.93826	4.0E+00	6.2E-02	2.5E-01	2.5E-01	7.5E-01	1.8E+01	4.6E+00
Pu-240	0.0582	2.5E-01	2.3E-01	5.8E-02	5.7E-02	1.7E-01	1.8E+01	1.1E+00
Pu-241	0.0034	1.5E-02	1.0E+02	1.5E+00	2.9E-01	8.8E-01	2.8E-01	8.3E-02
Pu-242	0.00024	1.0E-03	3.9E-03	4.0E-06	4.0E-06	1.2E-05	1.7E+01	7.0E-05
Am-241	--	1.8E+00	3.4E+00	6.1E+00	5.8E+00	1.7E+01	2.8E+01	1.7E+02
Am-241(d) - ingrowth from Pu-241				--	3.8E-02	1.1E-01	2.8E+01	1.1E+00
							Total =	172.0
						No. of Drums in excavation area=		3

Drum Type = Graphite
Pu Grams/drum = 9.9

Isotope	Weapons Grade Fraction	Grams/ Drum	Specific Activity (Ci/g)	Activity (Ci/drum) 1970	Activity (Ci/drum) 2002	Activity Drums in Exc. Area (Ci)	MEI CAP-88 Unit Dose (mrem/Ci)	Dose/ Drum (mrem)
Pu-238	0.00012	1.2E-03	1.7E+01	2.0E-02	1.6E-02	3.4E-01	1.7E+01	2.6E-01
Pu-239	0.93826	9.3E+00	6.2E-02	5.8E-01	5.8E-01	1.3E+01	1.8E+01	1.1E+01
Pu-240	0.0582	5.8E-01	2.3E-01	1.3E-01	1.3E-01	2.9E+00	1.8E+01	2.4E+00
Pu-241	0.0034	3.4E-02	1.0E+02	3.4E+00	6.7E-01	1.5E+01	2.8E-01	1.9E-01
Pu-242	0.00024	2.4E-03	3.9E-03	9.3E-06	9.3E-06	2.0E-04	1.7E+01	1.6E-04
Am-241	--	0.0E+00	3.4E+00	0.0E+00	0.0E+00	0.0E+00	2.8E+01	0.0E+00
Am-241(d) - ingrowth from Pu-241				--	8.8E-02	1.9E+00	2.8E+01	2.5E+00
							Total =	15.9
						No. of Drums in excavation area=		22

Drum Type = Non Combustibles
Pu Grams/drum = 3.6

Isotope	Weapons Grade Fraction	Grams/ Drum	Specific Activity (Ci/g)	Activity (Ci/drum) 1970	Activity (Ci/drum) 2002	Activity Drums in Exc. Area (Ci)	MEI CAP-88 Unit Dose (mrem/Ci)	Dose/ Drum (mrem)
Pu-238	0.00012	4.3E-04	1.7E+01	7.3E-03	5.7E-03	1.6E-01	1.7E+01	9.6E-02
Pu-239	0.93826	3.4E+00	6.2E-02	2.1E-01	2.1E-01	5.9E+00	1.8E+01	3.8E+00
Pu-240	0.0582	2.1E-01	2.3E-01	4.8E-02	4.8E-02	1.3E+00	1.8E+01	8.8E-01
Pu-241	0.0034	1.2E-02	1.0E+02	1.2E+00	2.4E-01	6.9E+00	2.8E-01	7.0E-02
Pu-242	0.00024	8.6E-04	3.9E-03	3.4E-06	3.4E-06	9.4E-05	1.7E+01	5.9E-05
Am-241	--	0.0E+00	3.4E+00	0.0E+00	0.0E+00	0.0E+00	2.8E+01	0.0E+00
Am-241(d) - ingrowth from Pu-241				--	3.2E-02	8.9E-01	2.8E+01	9.0E-01
							Total =	5.8
						No. of Drums in excavation area=		28

Drum Type = 744 Sludge
Pu Grams/drum = 1

Isotope	Weapons Grade Fraction	Grams/ Drum	Specific Activity (Ci/g)	Activity (Ci/drum) 1970	Activity (Ci/drum) 2002	Activity Drums in Exc. Area (Ci)	MEI CAP-88 Unit Dose (mrem/Ci)	Dose/ Drum (mrem)
Pu-238	0.00012	1.2E-04	1.7E+01	2.0E-03	1.6E-03	3.1E-03	1.7E+01	2.7E-02
Pu-239	0.93826	9.4E-01	6.2E-02	5.8E-02	5.8E-02	1.2E-01	1.8E+01	1.1E+00
Pu-240	0.0582	5.8E-02	2.3E-01	1.3E-02	1.3E-02	2.7E-02	1.8E+01	2.4E-01
Pu-241	0.0034	3.4E-03	1.0E+02	3.4E-01	6.8E-02	1.4E-01	2.8E-01	1.9E-02
Pu-242	0.00024	2.4E-04	3.9E-03	9.4E-07	9.4E-07	1.9E-06	1.7E+01	1.6E-05
Am-241	--	0.0E+00	3.4E+00	0.0E+00	0.0E+00	0.0E+00	2.8E+01	0.0E+00
Am-241(d) - ingrowth from Pu-241				--	8.8E-03	1.8E-02	2.8E+01	2.5E-01
							Total =	1.6
						No. of Drums in excavation area=		2

Drum Type = Combustibles
Pu Grams/drum = 0.5

Isotope	Weapons Grade Fraction	Grams/ Drum	Specific Activity (Ci/g)	Activity (Ci/drum) 1970	Activity (Ci/drum) 2002	Activity Drums in Exc. Area (Ci)	MEI CAP-88 Unit Dose (mrem/Ci)	Dose/ Drum (mrem)
Pu-238	0.00012	6.0E-05	1.7E+01	1.0E-03	7.9E-04	5.1E-02	1.7E+01	1.3E-02
Pu-239	0.93826	4.7E-01	6.2E-02	2.9E-02	2.9E-02	1.9E+00	1.8E+01	5.3E-01
Pu-240	0.0582	2.9E-02	2.3E-01	6.7E-03	6.7E-03	4.3E-01	1.8E+01	1.2E-01
Pu-241	0.0034	1.7E-03	1.0E+02	1.7E-01	3.4E-02	2.2E+00	2.8E-01	9.7E-03
Pu-242	0.00024	1.2E-04	3.9E-03	4.7E-07	4.7E-07	3.0E-05	1.7E+01	8.1E-06
Am-241	--	0.0E+00	3.4E-03	0.0E+00	0.0E+00	0.0E+00	2.8E+01	0.0E+00
Am-241(d) - ingrowth from Pu-241				--	4.4E-03	2.9E-01	2.8E+01	1.3E-01
							Total =	0.8

Remaining No. of Drums that "fit" into the excavation waste volume = 65
Total no. of drums of all types in waste zone = 120

Table 3. Total activity and activity concentrations in the excavated waste by waste type.

Activity in Excavated Waste Volume (Ci) for RFO Waste Type:

Isotope	741	Graphite	Non-combustible	744	Combustible	Total	Waste Zone (ci/g)
Pu-238	2.0E–02	3.4E–01	1.6E–01	3.1E–03	5.1E–02	5.7E–01	1.5E–08
Pu-239	7.5E–01	1.3E+01	5.9E+00	1.2E–01	1.9E+00	2.1E+01	5.5E–07
Pu-240	1.7E–01	2.9E+00	1.3E+00	2.7E–02	4.3E–01	4.9E+00	1.3E–07
Pu-241	8.8E–01	1.5E+01	6.9E+00	1.4E–01	2.2E+00	2.5E+01	6.5E–07
Pu-242	1.2E–05	2.0E–04	9.4E–05	1.9E–06	3.0E–05	3.4E–04	8.9E–12
Am-241	1.8E+01	1.9E+00	8.9E–01	1.8E–02	2.9E–01	2.1E+01	5.4E–07
					Total =	72.3	1.9E–06
# of drums =	3	22	28	2	65	120	
lbs/drums =	490	254	253	585	183		
Net g/drum =	1.88E+05	8.13E+04	8.08E+04	2.32E+05	4.90E+04		
Waste g/cm^3 =	0.91	0.39	0.39	1.11	0.24		
Waste g =	5.65E+05	1.79E+06	2.26E+06	4.63E+05	3.19E+06	8.27E+6	
		Total soil mass (g) in excavated waste zone (50%) =				3.01E+07	

Table 4. Stack radionuclide emission rates calculated using Method 2 and comparison to Method 1 emission rates.

Dust loading factor (g/m^3) =	0.5	From NUREG/CG-2651,1982
Dust suppression factor =	0.5	From EPA AP-41 (2 waterings/day)
Respirable activity fraction =	0.4	Krey et al., 1974
Glovebox exhaust ventilation rate (m^3/hr) =	1.2E+04	6860 cfm
(hr/yr) =	2.2E+03	90 days continuous
DF for two HEPA filters =	9.00E06	From ERDA 76-29

Nuclide	Waste Zone (ci/g)	Respir. Conc. (Ci/m^3)	Stack Release Unabated (Ci/y)	Stack Release Abated (Ci/y)	Method 1 Abated (Ci/y)	Method 2/ Method 1
Pu-238	1.5E–08	1.5E–09	3.8E–02	4.2E–09	1.7E–09	2.5
Pu-239	5.5E–07	5.5E–08	1.4E+00	1.6E–07	7.5E–08	2.1
Pu-240	1.3E–07	1.3E–08	3.2E–01	3.6E–08	1.7E–08	2.1
Pu-241	6.5E–07	6.5E–08	1.6E+00	1.8E–07	9.9E–08	1.8
Pu-242	8.9E–12	8.9E–13	2.2E–05	2.5E–12	8.8E–13	2.8
Am-241	5.4E–07	5.4E–08	1.4E+00	1.5E–07	1.5E–07	1.0

Abated emission rates then were calculated by dividing the unabated emission rate by the DF for two HEPA filters (9E+06) as described in Method 1.

Table 4 also compares the emission rates calculated using this method with those calculated using Method 1. Method 2 gives results that are a factor of 1 to 3 higher for the plutonium and americium isotopes examined, a relatively small difference that provides reasonable confidence in the calculated source terms. Because total dose impacts are calculated from the sum of the individual radionuclide toxicity and release rates, both Method 1 (all radionuclides) and Method 2 (plutonium isotopes to Am-241 only) emission rates were evaluated in the dose assessment.

2.5 Assessment of the Nonradiological Source Term

For nonvolatile contaminants, emission rates were calculated for most constituents based on the OU 7-10 inventory values given in Einerson and Thomas (1999) (see Table 5). Two exceptions are mercury and polychlorinated biphenyls (PCBs), which were retained from the original Stage II assessment, even though the inventories for these two contaminants are reported as unknown in Einerson and Thomas (1999). Mercury inventory values were taken from Liekhus (1991) and PCB inventory was taken from Smith and Kudera (1996).

Table 5. Nonradiological contaminant inventory with potential inhalation hazards.

Contaminant	Mass (g)	C = carcinogen N = noncarcinogen
Nonvolatile		
Asbestos	4.0E+05	C
Beryllium (	7.7E+04	C
Polychlorinated biphenyls	2.7E+02	C
Mercury	1.0E+05	N
Zirconium	1.5E+07	N
Lead	5.2E+06	a
Volatile		
Carbon tetrachloride	9.4E+07	C
Tetrachloroethene	2.7E+07	C
Chloroform (trichloromethane)	1.6E+05	C
Methylene chloride	1.6E+05	C
Trichloroethene	2.5E+07	C/N
1,1,1-Trichloroethane	2.2E+07	N

a. Lead, which is not listed as an Idaho toxic air pollutant, is controlled based on a quarterly arithmetic-average ambient air quality standard of 1.5 ug/m^3 (IDAPA 58.01.01.577.07).

Emission rates for VOCs were calculated from partial vapor pressures of the waste mixture, which was conservatively assumed to be all Series 743 sludge (Clements 1982), which is the waste with the highest VOC and carbon tetrachloride content. Two additional organics from Einerson and Thomas (1999) (chloroform and methylene chloride) were included in the mixture, though they are not listed as components of Series 743 sludge in that document.

The previous Stage II analysis demonstrated that carbon tetrachloride is by far the greatest risk driver. Other contaminants listed in Einerson and Thomas (1999) were not evaluated in this analysis because of their relatively low inventories and low toxicity criteria compared to the VOCs evaluated (e.g., Freon-113, acetone, and ethyl alcohol), or because they are not an inhalation hazard (e.g., potassium nitrate, sodium chloride, and sodium sulfate).

2.5.1 Nonvolatile Contaminants

Nonvolatile contaminants were assumed to be suspended with soil as particulate and were evaluated in the same manner as radionuclides (see Equation [1]). In addition to the contaminants in the waste, emissions of particulate matter less than 10-μm in diameter (PM_{10}) from fugitive dust suspension within the RCS and criteria pollutant (i.e., NO_2, SO_2, CO, and PM_{10}) emissions from the diesel backhoe and generator were evaluated (see Section 2.6, "Other Emission Sources"). The spreadsheet calculations for all nonvolatile contaminant emission rates are included in Appendix A. For TAP contaminants that are noncarcinogenic (i.e., mercury, zirconium, and PM_{10}), short-term (24-hour) average emission rates were calculated to be consistent with the 24-hour concentration averaging time specified in the Idaho toxic rules (IDAPA 58.01.01.210). Lead, which has a quarterly average ambient air quality standard of 1.5 g/m^3 (IDAPA 58.01.01.577.07), also was evaluated using a maximum 24-hour emission rate.

Mercury was assumed to be suspended as a liquid attached to dust particles rather than as a vapor (1) because of its physical form in the waste (pint bottles or in batteries), (2) the relatively low ambient temperatures during operations (vapor emissions of mercury are normally only of concern in thermal treatment processes), and (3) the spotty and unknown quantities of mercury in OU 7-10 (Einerson and Thomas 1999). However, to confirm mercury vapors would not pose a potential problem, screening calculations were performed to estimate maximum possible mercury vapor release rates and downwind impacts. These calculations, which assumed that the entire PGS was at saturated mercury concentration (2.6 ppm), confirmed no unacceptable downwind impacts (i.e., levels did not exceed the public acceptable ambient concentrations [AAC] or worker occupational exposure limit [OEL]).

2.5.2 Volatile Contaminants

Volatile contaminant emissions were evaluated for four potential pathways: (1) vapor releases from air-filled pore spaces in the excavated soil, (2) volatilization of VOCs in solution with soil water in the water-filled pore spaces of the excavated soil, (3) releases from undisturbed exposed waste at the digface walls, and (4) releases from waste exposed in the PGS.

2.5.2.1 Vapor and Dissolved Aqueous Phase Releases from Excavated Soil. The saturated vapor concentration (C_{si}, g/m^3) at the waste source is calculated using the Ideal Gas Law:

$$C_{si} = \frac{p_i MW_i}{R\ T} \tag{2}$$

where

p_i = partial vapor pressure of component i in a waste mixture (atm)

MWi = molecular weight of component i (g/mol)

R = gas constant (m^3-atm/mol-K)

T = soil temperature (K).

The partial vapor pressures (p_i) were calculated using Raoult's Law (Klotz and Rosenberg 1974) as the product of the pure component vapor pressure (p_{oi}) and the mole fraction (X_i):

$$p_i = p_{io} \; X_i \quad . \tag{3}$$

For excavated soil, pure component vapor pressures were obtained for 298 K (25°C) from *Dense Chlorinated Solvents and other DNAPLs in Groundwater: History, Behavior, and Remediation* (Pankow and Cherry 1996), which is a conservatively high temperature assumption for the unheated RCS.

To determine mole fractions (X_i) for the various organic constituents, it was conservatively assumed that all of the waste in the excavation area is Series 743 sludge, which is the waste type with the highest amount of hazardous organic constituents (Einerson and Thomas 1999). Although this assumption is not consistent with the assumptions in the radiological assessment (where other waste types with high plutonium loading were assumed to fill the waste zone), it conservatively bounds the calculated nonradiological risk and is necessary because the real mix of drum types that is actually in the excavation area is not known. However, because of this inconsistent assumption, it is not appropriate to sum the radiological and nonradiological risk results together.

Mole fractions for each VOC in Series 743 sludge were determined by dividing the total number of moles for each constituent in the OU 7-10 inventory (Einerson and Thomas 1999) by the mole sum of all constituents in that waste (see Table 6). The number of moles for each constituent was calculated by dividing the total inventory for each constituent (g) by its molecular weight (g/mol). The oil components that are listed for Series 743 sludge (Texaco Regal machining oil and equipment lubricating oils) were included in the mole sum of the waste constituents because the oils are volatile and will affect the partial vapor pressures of the other constituents. The number of moles of oil in the Series 743 waste inventory (n) was calculated using information in Einerson and Thomas and Equation (4).

$$n = \frac{(V_t - \sum V_i)\, N\, f\, \rho}{MW} \tag{4}$$

where

V_t	=	total volume of organic liquids in a Series 743 waste drum (37 gal/drum)
Vi	=	sum of organic contaminant volumes in a Series 743 waste drum (25.2 gal/drum)
N	=	total number of drums (1,140)
f	=	conversion factor (3,785 cm^3/gal)
ρ	=	density of oil (0.865 g/cm^3) (Miller and Varvel 2001)
MW	=	molecular weight of oil (360 g/mol) (Miller and Varvel 2001).

Table 6. Volumes and mole fractions for organic constituents in Series 743 sludge drums.

Organic Constituent	Volume (gal/drum)	Mole Fraction
Carbon tetrachloride	13.6	0.49
Trichloroethene	3.95	0.15
1,1,1-Trichloroethane	3.7	0.13
Tetrachloroethene	3.95	0.13
Texaco Regal and lube oils	11.8	0.098
Chloroform	0.025	0.0011
Methylene chloride	0.028	0.0015

a. Calculated from data given in Einerson and Thomas (1999) and Miller and Varvel (2001).

The VOC vapor mass (M_{ai}, in g) and liquid mass (M_{li}, in g) in a unit volume of excavated soil for contaminant i were calculated using Equation (5).

$$W_c / W = \frac{V_i \, f \, \rho_i}{M_W} \tag{5}$$

where

ϕ_a = air-filled soil porosity (0.27) = total porosity (0.47) minus water-filled porosity (0.20)

ϕ_l = water-filled soil porosity (0.20, from unpublished neutron moisture probe measurements of disturbed RWMC soil covers south of OU 7-10 [NAT-3 through NAT-9] averaged over a year and from surface to bedrock)

H_i = dimensionless Henry's Law Constant at 298 K (25°C) (see Appendix A).

Some uncertainty is associated with using the Henry's Law Constant to calculate air-to-liquid partitioning for nondilute solutions. However, the relative effects of this uncertainty on the total VOC emission rates are small because the liquid-filled soil porosity releases (which use H_i in their calculation) are small compared to the other three assessed VOC emission pathways (which do not use H_i)—releases from air-filled soil pores, waste exposed at the digface, and waste exposed in the PGS.

The short-term averaged emission rate from excavated soil for contaminant i (E_{Ei} in g/second) was then calculated using Equation (6).

$$E_{Ei} = (M_{ai} + M_{li}) \, RR \left(\frac{1 \, day}{86400 \, s} \right) \tag{6}$$

where

RR = soil/waste daily retrieval rate (m^3/day)

Annual-average emission rate was calculated by multiplying the short-term emission rate by the ratio of operational time period (2,160 hours) to the total number of hours in a year (8,760).

2.5.2.2 Vapor Releases from Nonexcavated Waste Exposed at the Digface Walls. This source was calculated using Arnold's Open Landfill Model (Radian Corporation 1988; EPA 1990a), which is a generally accepted model used to calculate conservative emission rates from organic liquids in open (uncovered) landfills (see Equation [7]):

$$V_{0i} = 2\, X_i\, A \sqrt{\frac{D_i\, t}{\pi\, F_v}} \tag{7}$$

where

V_{0i} = cumulative vapor released over time, t, for contaminant i (m^3)

X_i = mole fraction

A = area of exposed digface walls (currently 70.4 m^2 [758 ft^2])

D_i = diffusion coefficient in air (m^2/second) (Lugg 1968; listed in Appendix A)

t = diffusion time (seconds) - assumed to be the 90-day operational period (7.8E+06 seconds)

F_v = Fick's Law correction factor (unitless)

π = 3.1416.

The Fick's Law correction factor (F_v) accounts for displacement of the air by the volatilizing constituent and is a function of the equilibrium vapor pressure of the constituent. This value was determined to be approximately 1.0 for all constituents based on a graph given in the *Air/Superfund National Technical Guidance Study Series* (EPA 1990a).

The emission rate for digface wall diffusion (E_{Di}, in g/second) was then calculated by using Equation (8):

$$E_{Di} = \frac{MW_i\, P\, V_{0i}}{R\, T\, t} \tag{8}$$

where

T = ambient undisturbed soil temperature (283 K [10°C]).

P = ambient pressure at INEEL (0.84 atm).

(Note: The remaining terms were previously defined.)

Because this pathway considers releases from undisturbed waste at the digface walls, a lower, more conservative temperature of 283 K (10°C) was assumed for the denominator in Equation (8). This value is

based on unpublished soil temperature measurements at 10-ft depth (midway through the waste layer) in two boreholes on the Subsurface Disposal Area (temperature range was 280 to 283 K [7 to 10°C]).

Additional consideration was given to assessing the potential increase in VOC emissions resulting from the negative pressure differential (nominally -1.0 in. of water) planned for the RCS. This negative pressure differential could theoretically cause a vacuuming effect at the soil/air interface, which might increase VOC emissions via soil gas advection. However, the planned pressure differential (-1 in. water, -0.07 in. of mercury) is relatively low—daily (24-hour) barometric pressure fluctuations in the area typically exceed this value by a factor of 2-3. This suggests that any increase in emissions solely due to this vacuuming effect would be relatively low. Calculations performed for material compatibility indicate that this vacuuming effect would result in a maximum emission increase of 2.5% during the time period when the most waste was exposed at the digface walls (complete excavation). At other phases of the excavation, the increase is far less. Based on these findings and the results of the final calculated risk values, the incremental increase in emissions from this pathway was considered to be relatively insignificant and was not evaluated further in the modeling.

2.5.2.3 Emissions from Exposed Waste Vaporization in the Packaging Glovebox System. The emission rates from waste vaporization in the gloveboxes were calculated using Equation (7.13) from *The Soil Chemistry of Hazardous Materials* (Dragun 1988). Equation (9) was developed by Shen (1981) for calculating the rate of vapor generation from pure chemicals placed on a soil surface:

$$E_i = 2\,P_{vi} W_A (L_A D_{Ai} V/(3.1416) f)^{1/2} (W_{ci}/W) \tag{9}$$

where

E_i	=	volumetric emission rate of component i (cm^3/second)
P_{vi}	=	equivalent vapor pressure = [vapor pressure (mm Hg)]/760
W_A	=	width of area occupied by the chemical or waste (cm)
L_A	=	length of area occupied by the chemical or waste (cm)
D_{Ai}	=	diffusion coefficient of the chemical in air (cm^2/second)
V	=	air velocity over the chemical (cm/second)
W_{ci}/W	=	weight fraction of the chemical in the waste (g/g)
f	=	correction factor = $(0.985 - 0.00775\,P_{vi})$.

For this calculation, pure component vapor pressures were taken from Pankow and Cherry (1996) for a conservatively high 298 K (25°C). Partial vapor pressures then were calculated using Equation (3). The dimensions W_A and L_A were assumed to be those of the waste carts in the PGS (0.8 by 1 m). Because one cart is in each of three gloveboxes, Equation (9) was multiplied by 3. The air velocity (V) across the waste in each glovebox was assumed to be 396 cm/minute (12.9 ft/minute), based on current glovebox design parameters of 300 ft^3/minute ventilation rate through a 3.3-ft wide by 7-ft tall cross-sectional area. The weight fraction of the chemical in the waste zone (W_c/W) was calculated using Equation (10).

$$W_c/W = \frac{n\,V_i\,f\,\rho_i}{n\,M_D + M_S} \tag{10}$$

where

n = number of drums in the waste zone (120 drums)

V_i = nominal drum loading for chemical i (gal/drum) (see Table 6)

f = 3,785 cm^3/gal

Δi = density of chemical i at 298 K (25°C) (g/cm^3) (Pankow and Cherry 1996)

M_D = weight of average Series 743 drum (waste Content Code 3)

= (509 to 75 lb)(454 g/lb) = 1.97E+05 g (Clements 1982)

M_S = soil mass in waste zone, assuming 50% fill (3.0E+07 g) (see Table 3).

The volumetric emission rate (E_i) calculated in Equation (9) was converted into the mass emission rate from waste vaporization (E_{Wi} in g/second) by using Equation (11):

$$E_{Wi} = E_i \, MW_i \, / \, G \tag{11}$$

where

MW_i = molecular weight (gram/mole) for component i

G = 24,860 cm^3/mole.

2.5.2.4 Total Stack Volatile Organic Compound Emission Rates. The total VOC emission rate (E_{Ti}, g/second) was calculated by adding the emission rates from excavated soil (E_{Ei}, both air-filled and liquid-filled soil pores), digface wall diffusion (E_{Di}), and material handling cell waste vaporization (E_{Wi}) (see Table 7):

$$E_{Ti} = E_{Ei} + E_{Di} + E_{Wi} \quad . \tag{12}$$

Table 7. Volatile organic compound emissions from excavated soils, the digface, and volatilization in the Packaging Glovebox System.

	Saturated Vapor Conc. (g/m3)	Vapor Mass in 1 m^3 soil (g/m3)	Liquid Mass in 1 m^3 soil (g/m3)	Release Rate: RCS- from Excavated Soil (g/s)	Release Rate: RCS -from Digface (g/s)	Release Rate: PGS - from Vaporization (g/s)	Release Rate: Short-term TOTAL (g/s)	Annual Avg Release Rate (g/s)
Carcinogens (annual average):								
CCl4	440	119	69	3.9E-03	2.1E-01	1.6E-01	3.8E-01	**9.3E-02**
PCE	21.9	5.91	5.8	2.5E-04	5.7E-02	2.3E-03	6.0E-02	**1.5E-02**
Chloroform	1.3	0.36	1.7	4.4E-05	3.7E-04	1.7E-06	4.2E-04	**1.0E-04**
Methylene Cl	2.8	0.77	6.2	1.5E-04	4.0E-04	3.6E-06	5.5E-04	**1.4E-04**
TCE	40	10.9	20	6.5E-04	5.8E-02	8.2E-03	6.7E-02	**1.6E-02**
Non-Carcinogens (short-term average) :								
TCE	40	10.9	20	6.5E-04	5.8E-02	8.2E-03	6.7E-02	**1.6E-02**
TCA	59	15.9	16	6.8E-04	4.8E-02	9.8E-03	5.9E-02	**1.5E-02**

2.6 Other Emission Sources

2.6.1 Emissions During Drum Storage

After segregation in the PGS, waste will be placed into 55- or 85-gal drums and transported to the Advanced Mixed Waste Treatment Project Facility, stored in a CERCLA storage area, or stored in Waste Management Facility-628 (with Resource Conservation and Recovery Act-permit modification). Small emissions of VOCs are possible during this storage phase. Previous analysis of maximum potential emissions during drum storage was done for the Stage II project (Abbott 2000) and the *Potential Air Emissions from the OU 7-10 Stage II CERCLA Storage Facility* (Abbott 1999). The latter evaluated emissions from storage of 1,500 drum-equivalents and determined that these emissions would be negligible compared to those calculated in this engineering design file for the operational phase of the project (from excavation, digface vaporization, and volatilization in the PGS). Because the current project will be generating a significantly smaller number of drums for storage (estimated 600 to 700), maximum annual contaminant emission rates during any storage period still will be insignificant compared to those evaluated for the excavation and glovebox phases of the project and are not evaluated further.

2.6.2 Diesel Exhaust Emissions

Diesel exhaust emissions were evaluated for two sources: (1) the 110-hp (82-kW) RCS backhoe excavator and (2) a 200-kW emergency diesel generator. The current estimates for operating time are 17 hours per day (70% of the time) for the backhoe and 10 hours per month for the diesel generator (total of 520 hours per month). Criteria air pollutant emissions were estimated using AP-42 (EPA 1995a) emissions factors for large uncontrolled gas turbines (AP-42, Table 3.1-1). For sulfur dioxide emission estimates, the sulfur content of the diesel fuel was assumed to be 0.067%, which is the maximum given for #2 diesel in the INEEL diesel supplier's (Sinclair Oil Corporation) specification sheet. The calculated emission rates and the resulting maximum ambient air concentrations are provided in Section 2. For these noncarcinogenic criteria air pollutants, modeled air concentration results were compared to IAAQS/NAAQS and prevention of significant deterioration and significant impact levels.

3. DOSE ASSESSMENT AND AIR DISPERSION MODELING

3.1 Radionuclides

3.1.1 Model

The CAP-88 dose assessment code (EPA 1990b) was used with the NESHAP default parameters to determine the maximum effective dose equivalent (in mrem/year) from radionuclide emissions during the operational period. A workstation version of the mainframe CAP-88 model traditionally has been used at the INEEL for NESHAP compliance and State of Idaho air permitting because of its better capabilities to model progeny transport and examine specific receptor location doses.

3.1.2 Source Parameter Input

Emissions were modeled as a ground-level point source to conservatively bound the downwind receptor impacts for any stack or vent design. That is, any elevated stack release would result in lower downwind air concentrations at ground level than those calculated here. In addition, if the release point is through a roof vent or short stack, the plume would be initially diluted by building wake effects that also would reduce near field concentrations compared to those calculated using the point source assumptions in this assessment.

3.1.3 Meteorological Input File

The input file was a 10-year joint frequency "STAR" file (CFA.STR) developed from the 1987 to 1996 10-m high INEEL Central Facilities Area (CFA) meteorological tower data (CFA.10Y) by the Idaho Falls, Idaho, National Oceanic and Atmospheric Administration (NOAA) office. Wind data from CFA was used because a reliable long-term data set does not exist for the RWMC. The NOAA data incorporates calm hours into the lowest wind speed class.

3.1.4 Receptor Locations

The two receptor locations evaluated are described below:

1. **Maximum exposed individual:** This is the location of the maximum annual INEEL site boundary air concentration (and dose). This location was determined by CAP-88 (based on the source release parameters and the meteorological file used) to occur 5.9 km south-southwest of the RWMC. The dose calculated at this location is based on continuous exposure to inhalation, ground deposition, and immersion, and effectively bounds any real member of the public that might reside near the INEEL (including those receptors specified for NESHAP compliance). The model output files for these runs are SB-MEI1.CAP and SB-MEI2.CAP, which are maintained by the author.

2. **Maximum worker:** This is the location of maximum air concentration in any direction (determined by CAP-88 to be east-northeast) at a worst-case (minimum for modeling purposes) dispersion distance of 100 m. This location is meant to represent a reasonable worst-case exposure location for all workers because it assumes an individual worker remains at that exact location (east-northeast of the source) continuously for the entire work year (2,000 hours). Closer distances are not assessed because of (1) the high uncertainty of the dispersion model at distances less than 100 m, (2) the model point source algorithm would produce unrealistically high air concentrations, and (3) exact worker locations and residence times relative to the wind directions are impossible to predict. Worker doses do not include the ingestion pathway because no food products are grown at the working location. The worker inhalation dose was scaled to a higher breathing rate

(3.3E-04 m^3/second) and 2,000 hours per year occupancy (2,400 m^3 per year, compared to the 8,030 m^3 per year CAP-88 default), and external doses were scaled to 2,000 hours per year occupancy. The model output files for these runs are WORK1.CAP and WORK2.CAP, which are maintained by the author.

3.2 Nonradiological Contaminants

The SCREEN3 model (EPA Version 95250, EPA 1995b) was initially used to assess worst-case TAP concentrations in accordance with IDAPA 58.01.01.210 (TAP rules) and for assessment of maximum on-Site worker impacts. The SCREEN3 is a first-level screening tool that provides an upper-bound estimate of the maximum 1-hour averaged air concentration. This is because it assumes worst-case dispersion (stability class and wind speed) conditions that likely would not persist during both transport to the receptor or over the longer receptor averaging times of concern. For ambient air TAP assessment, SCREEN3 1-hour concentrations were converted to the required ambient air averaging times of 24-hours (for noncarcinogens) and annual average (for carcinogens) by multiplying by persistence factors of 0.4 and 0.125, in accordance with the Idaho TAP rules. For on-Site worker impacts, the SCREEN3 results were converted to 8-hour averages by multiplying by a persistence factor of 0.7 (EPA 1992). For evaluation of 3-hour SO_2 impacts from the diesel exhaust emissions, the 1-hour SCREEN3 results were multiplied by a persistence factor of 0.9 (EPA 1992).

The SCREEN3 was run with a unit (1 g/second) release rate to obtain output in $\mu g/m^3$ per g/second of any contaminant released. Individual contaminant concentrations ($\mu g/m^3$) then were calculated in a spreadsheet by multiplying the SCREEN3 output ($\mu g/m^3$ per g/second) by the appropriate persistence factor and contaminant emission rate (g/second). The source was modeled as a ground-level point source. Appropriate modeling criteria for TAPs and the criteria pollutants from diesel exhaust are summarized in Table 8. For TAPs, the appropriate criteria are (1) 24-hour average AACs for noncarcinogens, as given in IDAPA 58.01.01.585, and (2) annual average acceptable ambient concentrations for carcinogens (AACCs) as given in IDAPA 58.01.01.586. The AACs and AACCs listed in Table 8 are values currently listed in the IDAPA regulations. These current values are the same as or lower than the original values listed in the 1993 Idaho TAP Policy.

3.3 Refined Modeling

For carbon tetrachloride, the SCREEN3 results indicated an exceedance of the AACC. Therefore, the refined air quality model, ISCST3 (EPA Version 02035) was used to reassess the annual average air concentration. The following input parameters were used in the modeling run (output file: Run2.dta):

3.3.1 Source Input

The following source inputs were used:

- Ground-level point source located at universal transverse mercator 335045.7 east, 4818161.1 north, and elevation = 1,527.9 m
- Stack gas exhaust temperature set to 289 K (15°C)
- Negligible stack exit velocity set to simulate a ground-level (worst-case) plume height.

Table 8. Appropriate modeling criteria for toxic air pollutants and criteria air pollutants.

Receptor: Pollutant Category	Emission Rate	Receptor Location	Concentration Averaging Time	1-Hour Persistence Factor	Concentration Criteria
Ambient air: toxic pollutants					
Public: noncarcinogen	24-hour average	Nearest public access[a] EBR-I—2.9 km	24-hour	0.4	TAP AAC[c]
Public: carcinogen	Annual average	Nearest Site boundary[a] 5.9 km	Annual	0.125	TAP AACC[d]
Worker: all	Short-term	100 m	8-hour[b]	0.7	OEL[e]
Ambient air: criteria pollutants					
NO_2	Annual	Nearest public access	Annual	0.125	IAAQS and NAAQS
SO_2	Short-term Short-term Annual	Nearest public access	3-hour 24-hour annual	0.9 0.4 0.125	IAAQS and NAAQS
CO	Short-term Short-term	Nearest public access	1-hour 8-hour	None 0.7	IAAQS and NAAQS
PM_{10}	Short-term Annual	Nearest public access	24-hour annual	0.4 0.125	IAAQS and NAAQS

a. In accordance with IDAPA 58.01.01.210.
b. For TAPs that have an 8-hour TWA occupational exposure criteria.
c. Acceptable ambient concentration increments listed in IDAPA 58.01.01.585.
d. Acceptable ambient concentration for carcinogens increments listed in IDAPA 58.01.01.586.
e. Occupational exposure limits, normally an American Conference of Government Industrial Hygienist threshold limit value (used in this assessment) or an Occupational Safety and Health Administration permissible exposure level.

EBR-I = Experimental Breeder Reactor-I
IAAQS = Idaho Ambient Air Quality Standards
IDAPA = Idaho Administrative Procedures Act
NAAQS = National Ambient Air Quality Standards
TAP = toxic air pollutant
TWA = time-weighted average

3.3.2 Meteorological Data

The following meteorological data were used:

- Three years (1993 to 1995) of sequential hourly surface data from the CFA 10-m meteorological tower (8 km northeast of the RWMC), processed by the NOAA Idaho Falls office. The NOAA has determined that the CFA data are the most appropriate for assessing RWMC releases because of new construction near the RWMC meteorological tower, which may have compromised the validity of the data at that location.

- Upper air data (hourly mixing heights) taken from Salt Lake City, which is the closest station with upper air data. This parameter will have a negligible effect on the ground-level release modeled in this analysis.

3.3.3 Receptor Input

- **Worker impacts**—The ISC3 modeling run evaluated a polar receptor grid with 10-degree radials and distances intervals of 50, 100, 200, 500, and 1,000 m from the source. The 50-m minimum distance is closer than the 100-m minimum distance evaluated in the SCREEN3 and CAP-88 modeling runs and was done to ensure maximum conservatism in assessment of the risk driver, carbon tetrachloride. Receptor elevations were set to the source elevation (1,528 m).

- **Public impacts**—Discrete receptors were placed along U.S. Highway 20/26, EBR-I and EBR-I access road, and the southern INEEL boundary. Receptors were placed at 100-m intervals in locations of maximum impact (in the general downwind directions of the RWMC). Receptor elevations were taken from the INEEL Geographical Information System database.

4. SHORT-TERM RISK AND HAZARD INDEX

4.1 Toxic Air Pollutants

Carcinogenic risks from potential short-term exposures (short-term risk) to TAPs were evaluated for the maximum worker and public access (EBR-I) impact locations. The short-term risks were calculated using the State of Idaho AACCs (μg/m^3 per 1E-06 risk) which assume 70 years (25,550 days) of exposure. These AACCs were developed from EPA unit risk factors, which are risk per μg/m^3 assuming 70 years of chronic exposure. The risk for 1 year of exposure to modeled air concentration at each receptor (C_r) was calculated using Equation (13).

$$Risk = \left(\frac{C_r \ (1E-06 \ risk)}{AACC} \right) \left(\frac{T_E}{25{,}550 \ days} \right) \tag{13}$$

where

C_r = receptor annual average air concentration (μg/m^3)

$AACC$ = acceptable ambient concentration for a carcinogen (μg/m^3 per 1E-06 risk)

T_E = short-term scenario exposure time (days).

For both workers and the public at EBR-I, T_E was assumed to be 200 days (4 days per week, 50 weeks per year).

For nonradiological contaminants, hazard quotients were calculated by dividing the modeled air concentrations by EPA reference concentrations as published in the *Health Affects Assessment Summary Tables* (EPA 1997a; EPA 2001).

4.2 Radionuclides

In addition to the dose assessment for NESHAP compliance, excess lifetime cancer incidence risks were calculated for both worker and public exposures. Only inhalation exposure was assessed because of the following:

- Based on the CAP-88 results, inhalation dose (and therefore risk) account for more than 95% of the total dose (risk)
- For a short-term (90-day) source, buildup in the food-chain is insignificant (relative to conservative CAP-88 assessment of direct inhalation)
- No food products are grown on-Site or near the assessed MEI location.

Risk was calculated by multiplying the unit release CAP-88 air concentrations (pCi/m^3 per Ci/year at both the worker and MEI receptor locations) by (1) the calculated emission rates, (2) the appropriate receptor annual breathing rates (m^3/year), and (3) the appropriate radionuclide inhalation slope factor (risk/pCi) from the *Health Affects Assessment Summary Tables* for radionuclides. Breathing rates taken from recent recommendations in EPA (1997b) for long-term (e.g., seasonal or annual) exposures are listed below:

- **Public:** 15.2 m^3/day × 7 days/week × 50 weeks/year = 5,320 m^3/year
- **Outdoor workers:** 1.3 m^3/hour × 2,000 hours/year = 2,600 m^3/year.

5. RESULTS

5.1 Radionuclides

The dose assessment results for all of the radionuclides using Method 1 are contained in Table 9. Table 10 contains the dose results for the Pu/Am-241 risk drivers using Method 2. The dose results from both of these methods are very similar, with the Method 2 results being higher than the Method 1 results by 34%.

The unabated Method 2 MEI results (71 mrem) significantly exceed the NESHAP monitoring criteria of 0.1 mrem (1% of the 10 mrem per year NESHAP standard). In addition, the radionuclides that contribute more than 10% of the total dose are Pu-239 and Am-241. Therefore, the project will require NESHAP stack monitoring for these radionuclides.

The abated Method 2 MEI results (7.9E-06 mrem) are significantly less than the 10 mrem per year NESHAP standard and are insignificant compared to the total INEEL dose from all other facilities (i.e., 4.65E-02 mrem for 1996) (DOE-ID 1997).[h]

The calculated Method 2 worker dose (3.3E-03 mrem) is a very small fraction (0.0002% or less) of the INEEL administrative control level from the *Manual 15A - INEEL Radiological Control Manual* (Radiological Control 2002) of 700 mrem/year and the 10 CFR 835, "Occupational Radiation Protection Exposure," control level of 5,000 mrem/year.

Table 11 contains conservative estimates of the predicted increase in lifetime cancer incidence from the project: 5.5E-13 for the MEI and 4.0E-10 for the worker. These levels are far below the 1E-06 to 1E-04 range considered acceptable by EPA.

5.2 Nonradiological Contaminants

The calculated emissions and modeled air concentrations for the diesel exhaust emissions are contained in Table 12. All pollutants are significantly less than applicable criteria.

The air modeling results for nonradiological contaminants are contained in Table 13. All concentrations are less than applicable State of Idaho TAP criteria (AACCs and AACs) for ambient air receptors and less than applicable OELs for worker exposures. Short-term cancer risks are less than 1E-06 for the public and less than 1E-05 for RWMC workers.

In all cases, carbon tetrachloride results in the highest impacts. The maximum INEEL boundary concentration for this TAP (0.017 g/m^3) is 26% of the AACC (0.067 µg/m^3). The maximum 8-hour occupational exposure (31 mg/m^3) is 29% of the OEL (31 mg/m^3). The predicted short-term risks summed over all TAPs are 5.1E-09 for a member of the public at EBR-I and 6.7E-06 for a worker at 50 m.

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h. J. F. Graham, LMITCO, Letter to J. E. Medema, DOE-ID, JFG-43-98, (Original NESHAPs report value [3.14E-02 mrem] was corrected to this higher value in this letter), September 10, 1998.

Table 9. Radiological dose results for the OU 7-10 Glovebox Excavator Method Project—Method 1.

	Stack Release		CAP-88 Unit Dose		MEI Dose		Worker	MEI
	Unabated	Abated	MEI	Worker	Unabated	Abated	Dose	Cumulative
Nuclide	(Ci)	(Ci)	(mrem/Ci)	(mrem/Ci)	(mrem)	(mrem)	(mrem)	Fraction
Am-241	1.3E+00	1.5E-07	2.8E+01	1.2E+04	3.7E+01	4.1E-06	1.7E-03	0.7046
Pu-239	6.7E-01	7.5E-08	1.8E+01	7.5E+03	1.2E+01	1.4E-06	5.6E-04	0.9370
Pu-240	1.5E-01	1.7E-08	1.8E+01	7.5E+03	2.8E+00	3.1E-07	1.3E-04	0.9902
Pu-238	1.5E-02	1.7E-09	1.7E+01	7.0E+03	2.6E-01	2.9E-08	1.2E-05	0.9951
Pu-241	8.9E-01	9.9E-08	2.8E-01	1.1E+02	2.5E-01	2.8E-08	1.1E-05	0.9999
U-238	5.9E-04	6.6E-11	6.2E+00	2.6E+03	3.6E-03	4.1E-10	1.7E-07	0.9999
U-234	2.8E-04	3.1E-11	6.9E+00	2.9E+03	1.9E-03	2.1E-10	8.9E-08	1.0000
Sr-90	6.6E-03	7.3E-10	5.7E-02	4.9E+00	3.8E-04	4.2E-11	3.6E-09	1.0000
Np-237	1.4E-05	1.5E-12	2.6E+01	1.1E+04	3.6E-04	4.0E-11	1.7E-08	
Pu-242	7.9E-06	8.8E-13	1.7E+01	7.1E+03	1.4E-04	1.5E-11	6.2E-09	
U-235	1.4E-05	1.5E-12	6.4E+00	2.7E+03	8.9E-05	9.9E-12	4.1E-09	
Cs-137	8.3E-04	9.3E-11	3.6E-02	6.8E-01	3.0E-05	3.3E-12	6.3E-11	
Y-90	6.6E-03	7.3E-10	3.6E-03	2.1E-01	2.4E-05	2.7E-12	1.5E-10	
Ni-63	4.7E-02	5.2E-09	3.4E-04	5.0E-02	1.6E-05	1.8E-12	2.6E-10	
Pb-210	5.3E-06	5.9E-13	2.0E+00	1.8E+02	1.1E-05	1.2E-12	1.0E-10	
Ba-137m	7.9E-04	8.8E-11	1.2E-02	3.5E+00	9.2E-06	1.0E-12	3.1E-10	
Ra-226	8.2E-06	9.1E-13	8.4E-01	1.9E+02	6.9E-06	7.6E-13	1.8E-10	
Po-210	5.3E-06	5.9E-13	1.0E+00	1.9E+02	5.3E-06	5.9E-13	1.1E-10	
Th-234	5.9E-04	6.6E-11	6.0E-03	8.4E-01	3.5E-06	3.9E-13	5.6E-11	
Th-230	8.2E-08	9.1E-15	1.3E+01	5.5E+03	1.0E-06	1.2E-13	5.0E-11	
U-236	1.5E-07	1.7E-14	6.5E+00	2.7E+03	9.8E-07	1.1E-13	4.6E-11	
Pa-231	9.6E-09	1.1E-15	2.6E+01	1.1E+04	2.5E-07	2.7E-14	1.1E-11	
Bi-214	8.2E-06	9.1E-13	2.8E-02	8.3E+00	2.3E-07	2.5E-14	7.6E-12	
Pa-234m	5.9E-04	6.6E-11	2.2E-04	6.7E-02	1.3E-07	1.5E-14	4.4E-12	
Ac-227	3.7E-09	4.1E-16	3.3E+01	1.4E+04	1.2E-07	1.4E-14	5.7E-12	
Co-60	1.6E-06	1.8E-13	6.8E-02	1.7E+01	1.1E-07	1.2E-14	3.1E-12	
Pa-233	1.4E-05	1.5E-12	6.1E-03	1.6E+00	8.5E-08	9.4E-15	2.4E-12	
Bi-210	5.3E-06	5.9E-13	1.2E-02	4.3E+00	6.2E-08	6.9E-15	2.5E-12	
Pb-214	8.2E-06	9.1E-13	5.4E-03	1.6E+00	4.4E-08	4.9E-15	1.4E-12	
Pa-234	9.5E-07	1.1E-13	3.9E-02	1.2E+01	3.7E-08	4.1E-15	1.2E-12	
Fe-55	3.8E-05	4.2E-12	4.2E-04	3.1E-02	1.6E-08	1.8E-15	1.3E-13	
Th-231	1.4E-05	1.5E-12	8.1E-04	1.3E-01	1.1E-08	1.2E-15	2.0E-13	
U-233	9.9E-10	1.1E-16	7.0E+00	2.9E+03	6.9E-09	7.7E-16	3.2E-13	
Th-227	3.6E-09	4.0E-16	6.0E-01	2.6E+02	2.2E-09	2.4E-16	1.0E-13	
C-14	7.5E-07	8.3E-14	1.8E-03	2.8E-04	1.3E-09	1.5E-16	2.3E-17	
H-3	1.2E-05	1.3E-12	3.8E-05	2.9E-03	4.4E-10	4.9E-17	3.7E-15	
Tc-99	2.0E-07	2.2E-14	1.8E-03	1.8E-01	3.6E-10	4.0E-17	4.0E-15	
Po-218	8.2E-06	9.1E-13	2.5E-05	1.2E-03	2.1E-10	2.3E-17	1.1E-15	
Ni-59	1.3E-06	1.4E-13	1.4E-04	2.3E-02	1.8E-10	2.0E-17	3.3E-15	
I-129	2.4E-10	2.7E-17	3.0E-01	3.7E+00	7.3E-11	8.2E-18	1.0E-16	
Th-229	1.0E-12	1.1E-19	3.5E+01	1.5E+04	3.6E-11	4.0E-18	1.8E-15	
Po-214	8.2E-06	9.1E-13	1.7E-06	5.0E-04	1.4E-11	1.5E-18	4.5E-16	
Fr-223	5.1E-11	5.6E-18	2.4E-03	3.9E-01	1.2E-13	1.3E-20	2.2E-18	
Th-232	1.2E-16	1.4E-23	1.8E+01	7.9E+03	2.2E-15	2.5E-22	1.1E-19	
Ra-228	7.6E-17	8.4E-24	3.3E-01	5.4E+01	2.5E-17	2.8E-24	4.5E-22	
Ac-228	7.5E-17	8.3E-24	2.2E-02	6.9E+00	1.6E-18	1.8E-25	5.8E-23	
				Total =	**5.3E+01**	**5.9E-06**	**2.4E-03**	

Table 10. Radiological dose impacts—Method 2.

Nuclide	CAP-88 Unit Dose MEI (mrem/Ci)	CAP-88 Unit Dose 100-m (mrem/Ci)	Stack Release Unabated (Ci/y)	Stack Release Abated (Ci/y)	Unabated MEI Dose (mrem/y)	Abated MEI Dose (mrem/y)	Abated 100-m Dose (mrem/y)
Pu-238	1.7E+01	7.0E+03	3.8E-02	4.2E-09	6.4E-01	7.1E-08	2.9E-05
Pu-239	1.8E+01	7.5E+03	1.4E+00	1.6E-07	2.6E+01	2.8E-06	1.2E-03
Pu-240	1.8E+01	7.5E+03	3.2E-01	3.6E-08	5.9E+00	6.5E-07	2.7E-04
Pu-241	2.8E-01	1.1E+02	1.6E+00	1.8E-07	4.6E-01	5.2E-08	2.1E-05
Pu-242	1.7E+01	7.1E+03	2.2E-05	2.5E-12	3.9E-04	4.3E-11	1.8E-08
Am-241	2.8E+01	1.2E+04	1.4E+00	1.5E-07	3.9E+01	4.3E-06	1.8E-03
			Total =	**5.3E-07**	**7.1E+01**	**7.9E-06**	**3.3E-03**

Table 11. Radiological cancer incidence—Method 2.

Normalized Air Concentration - MEI (pCi/m3 per Ci/y) =	6.20E-03	
Normalized Air Conc. - Worker (pCi/m3 per Ci/y) =	9.1	EPA Exposure Factors Handbook 1997
Annual Breathing Rate - MEI (m^3/y) =	5320	Adult male long-term average
Annual Breathing Rate - Worker (m^3/y) =	2600	Outdoor worker hourly average *2000 hrs/y

Nuclide	CAP-88 Unit Dose MEI (mrem/Ci)	CAP-88 Unit Dose Worker (mrem/Ci)	Abated Release (Ci/y)	CAP-88 Air Conc. (pCi/m^3) MEI	CAP-88 Air Conc. (pCi/m^3) 100-m	Inhalation Intake (pCi) MEI	Inhalation Intake (pCi) 100-m	Inh. Slope Factor (Risk/pCi)	Lifetime Cancer Incidence Risk MEI	Lifetime Cancer Incidence Risk 100-m
Pu-238	1.7E+01	7.0E+03	4.2E-09	2.6E-11	3.8E-08	1.4E-07	9.9E-05	3.36E-08	4.6E-15	3.3E-12
Pu-239	1.8E+01	7.5E+03	1.6E-07	9.6E-10	1.4E-06	5.1E-06	3.7E-03	3.33E-08	1.7E-13	1.2E-10
Pu-240	1.8E+01	7.5E+03	3.6E-08	2.2E-10	3.2E-07	1.2E-06	8.4E-04	3.33E-08	3.9E-14	2.8E-11
Pu-241	2.8E-01	1.1E+02	1.8E-07	1.1E-09	1.7E-06	6.0E-06	4.3E-03	3.34E-08	2.0E-13	1.4E-10
Pu-242	1.7E+01	7.1E+03	2.5E-12	1.5E-14	2.3E-11	8.2E-11	5.9E-08	3.13E-08	2.6E-18	1.9E-15
Am-241	2.8E+01	1.2E+04	1.5E-07	9.3E-10	1.4E-06	5.0E-06	3.6E-03	2.81E-08	1.4E-13	1.0E-10
Total =			**5.3E-07**	**3.3E-09**	**4.8E-06**	**1.7E-05**	**1.2E-02**	**--**	**5.5E-13**	**4.0E-10**

Table 12. Diesel combustion emissions and impacts.

Power output (kW) =	282	200 kw generator + 82 kw (110hp) backhoe - 3/1/2002
Percent sulfur in fuel (wt%) =	0.067	From Sinclair Oil, #2 diesel, spec sheet
Usage (hrs/month) =	520	17 hr/d x 30 d/mo (backhoe) + 10 hr/mo (generator) - 3/1/02

EPA AP-42, Table 3.1-1

Emissions Factors for Large Uncontrolled Gas Turbines

Pollutant	Ap-42 Emissions Factor (g/kW-hr)	Emission Rate Short-term (g/s)	Emission Rate Annual (g/s)	NAAQS Averaging Time	Max Unit Air Conc. (ug/m^3/g/s)	Max Air Conc. (ug/m^3)	PSD "Significant Impact" (ug/m^3)	NAAQS (ug/m^3)
NOx	3.41	0.267	0.04757	annual	0.457	0.02174	1	100
CO	0.233	0.018	N/A	1-hour	135	2.46	2000	40000
			N/A	8-hour	94	1.72	500	10000
SOx	0.330	0.026	N/A	3-hour	121	3.13	25	1300
			N/A	24-hour	54	1.39	5	365
			0.00460	annual	0.457	0.00210	1	80
PM-10	0.298	0.023	N/A	24-hour	54	1.26	5	150
			0.00416	annual	0.457	0.00190	1	50

Table 13. Nonradiological contaminant air concentration impacts.

SCREEN3 Model unit release air concentrations (ug/m3 per g/s):

	Averging Time	Downwind Distance (m) 50	100	2900	5900
	1-hour:		3.4E+04	135	51
	3-hour:		3.0E+04	1.2E+02	4.6E+01
	8-hour:		**2.4E+04**	94	36
	24-hour:		1.3E+04	**54**	20
	Annual:		4.2E+03	17	6
ISCST3	Annual:	**608**	193	**0.457**	**0.186**

	Public						Workers				
	State TAP Rules			Short-term Risk			Occupational Exposure			Short-term Risk	
	Annual Avg @INEEL Site Boundary			Annual Avg @EBR 1 (2900 m)			8-hour Average @ 100 m			Annual-Avg @ 50 m	
Carcinogens:	***ISC3*** Conc. (ug/m3)	AACC (ug/m3)	Ratio - Modeled/ AACC	***ISC3*** Conc. (ug/m3)	Ratio - Modeled/ AACC	Risk	***SCREEN3*** Conc. (ug/m3)	OEL (ug/m3)	Ratio - Modeled/ OEL	***ISC3*** Conc. (ug/m3)	Short-Term Risk
CCl4	1.7E-02	6.7E-02	2.6E-01	4.2E-02	6.3E-01	5.0E-09	8.9E+03	3.1E+04	2.9E-01	5.6E+01	6.6E-06
PCE	2.7E-03	2.1E+00	**1.3E-03**	6.7E-03	**3.2E-03**	2.5E-11	1.4E+03	1.7E+05	**8.3E-03**	9.0E+00	**3.3E-08**
Chloroform	1.9E-05	4.3E-02	**4.4E-04**	4.7E-05	**1.1E-03**	8.5E-12	9.8E+00	4.9E+04	**2.0E-04**	6.2E-02	**1.1E-08**
Methylene Cl	2.5E-05	2.4E-01	**1.1E-04**	6.2E-05	**2.6E-04**	2.0E-12	1.3E+01	1.7E+05	**7.5E-05**	8.3E-02	**2.7E-09**
TCE	3.0E-03	7.7E-01	**4.0E-03**	7.5E-03	**9.7E-03**	7.6E-11	1.6E+03	1.7E+05	**9.0E-03**	1.0E+01	**1.0E-07**
Asbestos[a,b]	1.0E-13	5.2E-04	**2.0E-10**	2.5E-13	**4.9E-10**	3.8E-18	5.3E-08	2.6E+02	**2.0E-10**	3.4E-10	**5.1E-15**
Be	2.0E-14	4.2E-03	**4.7E-12**	4.9E-14	**1.2E-11**	9.1E-20	1.0E-08	2.0E+00	**5.1E-09**	6.5E-11	**1.2E-16**
PCBs (Aroclor)	7.0E-17	1.0E-02	**7.0E-15**	1.7E-16	**1.7E-14**	1.3E-22	3.6E-11	5.0E+02	**7.2E-14**	2.3E-13	**1.8E-19**
					Total =	**5.1E-09**				***Total =***	**6.7E-06**
	24-hr Avg @ EBR 1										
Non-Carcinogens	***SCREEN3*** Conc. (ug/m3)	AAC (ug/m3)	Modeled/ AAC	EPA RfC (ug/m3)	Hazard Quotient (Conc/RfC)		***SCREEN3*** Conc. (ug/m3)	OEL (ug/m3)	Ratio - Modeled/ OEL		
TCE	3.5E-02	1.3E+04	**2.6E-06**	2.1E+01	1.7E-03		1.6E+03	2.7E+05	**5.8E-03**		
TCA	3.6E-02	9.6E+04	**3.8E-07**	1.0E+03	3.6E-05		1.4E+03	1.9E+06	**7.3E-04**		
Hg	2.1E-10	2.5E+00	**8.3E-11**	3.0E-01	6.9E-10		9.1E-08	5.0E+01	**1.8E-09**		
Pb[c]	1.1E-08	1.5E+00	**7.2E-09**	none	see AAC comparison		4.7E-06	1.5E+02	**3.1E-08**		
Zr	3.1E-08	2.5E+02	**1.2E-10**	none	see AAC comparison		1.4E-05	5.0E+03	**2.7E-09**		

a. AACC is 4e-6 fibers/cc. Converted to ug/m3 using 1.3e-7 mg/fiber for chrysotile (most common form) (Stage 1 Interim Action Air Emissions Evaluation).
b. OEL is 2 fibers/cc for chrysotile (most common form). Converted to ug/m3 using 1.3e-7 mg/fiber (Stage 1 Interim Action Air Emissions Evaluation).
c. Lead is not listed as an Idaho TAP. AAC value is the quarterly-average ambient air quality standard (IDAPA 58.01.01.577.07).

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Appendix A

Radiological and Nonradiological Source Term Calculations

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Appendix A

Radiological and Nonradiological Source Term Calculations

Pit 9 Non-Rad Source Term Calculations

M.L. Abbott Rev. 1 - 5/9/2002 Checked by MJCase 4/29/02

Non-volatile (dispersable metals, asbestos, PCBs):

1) Pit 9 waste volume (ft^3) =	110000		Total volume (ft3)= 750000
2) RFP fraction of pit volume =	0.5		
3) Waste distribution uncertainty factor =	2		
4) Waste+soil density (g/cm^3) =	1.2		
5) Dust Loading (g/m^3) =	0.5		
6) Dust suppression factor =	0.5		
7) Respirable activity fraction =	0.4		
8) Glove box Exhaust rate (m3/hr) =	1.2E+04	6860 cfm	
9) Total hr/yr for operations =	2.2E+03	90 days continuous	
10) DF for 2 HEPA filters =	9.00E+06		

13) GLOVEBOX containment

Contaminant	11) Total Pit 9 Inventory (g)	12) Soil Concentration (g/m^3)	12) Soil Concentration (g/g-soil)	Air Concentration Total (g/m^3)	Air Concentration Respirable (g/m^3)	14) **Stack Release Rate Short-term (g/s)**	14) **Stack Release Rate Annual Avg (g/s)**
Carcinogens (annual average):							
Asbestos	4.0E+05	7.5E+01	6.3E-05	1.6E-05	6.3E-06	2.3E-12	**5.6E-13**
Be	7.7E+04	1.5E+01	1.2E-05	3.0E-06	1.2E-06	4.3E-13	**1.1E-13**
PCB (Arochlor)	2.7E+02	5.1E-02	4.2E-08	1.1E-08	4.2E-09	1.5E-15	**3.8E-16**
Non-Carcinogens (short-term average):							
Hg	1.0E+05	1.3E+02	1.1E-04	2.7E-05	1.1E-05	**3.8E-12**	N/A
Pb	5.2E+06	6.7E+03	5.6E-03	1.4E-03	5.6E-04	**2.0E-10**	N/A
Zr	1.5E+07	1.9E+04	1.6E-02	4.0E-03	1.6E-03	**5.8E-10**	N/A

Volatile:

Revised 5/9/02 w/ Einerson and Thomas (1999) data

15) Subsurface Soil Temperature (K)=	298	(75 F, 25 C) - Rev. 1
16) Total soil porosity=	0.47	
17) Water-filled soil porosity=	0.20	
18) Air-filled soil porosity=	0.27	
19) Soil retrieval rate (m3/day)=	1.81	(Max 64 ft3/day - 3/2002 est. - INCREASE)

	11) **Total Pit 9 Inventory (g)**	**Molar Weight (g/mole)**	**moles (mol)**	(20) **Mole Fraction**	(21) **Pure Comp. Vapor Pressure (mm Hg)**	(22) **Partial Vapor Pressure (mm Hg)**	(23) **Henry's Law Constant** (dimensionless)	(24) **Diffusion Coefficient in air (m2/s)**
Carcinogens (annual average):								
CCl4	9.4E+07	153.92	6.1E+05	0.487	109	53.1	1.283	8.28E-06
PCE	2.7E+07	165.83	1.6E+05	0.130	18.9	2.45	0.749	7.39E-06
Chloroform	1.6E+05	119	1.3E+03	0.0011	194	0.21	0.154	8.88E-06
Methylene Cl	1.6E+05	85	1.9E+03	0.0015	415	0.62	0.091	1.04E-05
TCE	2.5E+07	131.39	1.9E+05	0.152	75	11.4	0.403	8.75E-06
Non-Carcinogens (short-term average)								
TCE	2.5E+07	131.39	1.9E+05	0.152	75	11.4	0.403	8.75E-06
TCA	2.2E+07	133.4	1.6E+05	0.132	124.6	16.4	0.719	7.94E-06
Non-hazardous:								
Machine/lube Oils	4.4E+07	360	1.2E+05	0.097				
		Sum =	1.25E+06	1.000				

VOC Emissions from Undisturbed Waste Exposed at Digface using Arnold's Open Landfill Model

Time waste exposed (s) =	7.78E+06	(90 days)
Surface area (m2) =	70.4	(758 ft2 - waste area side walls - 3/2002
Undisturbed soil Temp (K) =	283	unpublished SDA borehole measuremer

Fv = 1.0 (partial vapor pressures < 1%)

	Pure Comp. Vapor Pressure (mm Hg)	**Gas Volume Released (m3)**	**Gas Mass Released (g)**	**Release Rate (g/s)**
Carcinogens (annual average):				
CCl4	54	3.10E+02	1.64E+06	2.11E-01
PCE	8.0	7.82E+01	4.45E+05	5.73E-02
Chloroform	98	7.08E-01	2.89E+03	3.72E-04
Methylene Cl	218	1.07E+00	3.13E+03	4.02E-04
TCE	36.2	9.94E+01	4.49E+05	5.77E-02
Non-Carcinogens (short-term average):				
TCE	36.2	9.94E+01	4.49E+05	5.77E-02
TCA	61.7	8.21E+01	3.76E+05	4.84E-02
		Sum =	3.37E+06	4.33E-01

VOC Emissions from Waste Vaporization in Glove boxes Using Equation 7.13, Dragun (1988)

MHC Temperature (C) =	298	(heated - Avg=75F)
Area (m2) =		not used in calc
Wind speed (cm/s) =	6.6	5/8/02 design change of 300 cfm/23.3 ft2 X-sect area = 12.9 fpm
Width (cm)=	81.3	Cart in each box, from Mark Borland 4/15
Length (cm)=	102	Cart in each box, from Mark Borland 4/16
No. drums in waste zone=	120	
Soil mass in waste zone (g) =	3.01E+07	

	Pure Comp. Vapor Pressure (mm Hg)	Equivalent Vapor Pressure (mm Hg)	743 Drum Loading (gal)	density at 25C (g/cm3)	(g/g)	for 3 simultaneous glovebox ops Emission Rate volume (cm^3/s)	mass (g/s)
Carcinogens (annual average):							
CCl4	109	53.1	13.8	1.59	1.9E-01	2.6E+01	**1.64E-01**
PCE	18.9	2.5	4.0	1.63	5.5E-02	3.4E-01	**2.3E-03**
Chloroform	194	0.2	0.05	1.49	6.3E-04	3.6E-04	**1.7E-06**
Methylene Cl	415	0.6	0.05	1.33	5.6E-04	1.1E-03	**3.6E-06**
TCE	75	11.4	4.0	1.46	4.9E-02	1.5E+00	**8.2E-03**
Non-Carcinogens (short-term average) :							
TCE	75	11.4	4.0	1.46	4.9E-02	1.5E+00	**8.2E-03**
TCA	124.6	16.4	3.7	1.35	4.2E-02	1.8E+00	**9.8E-03**
						Sum =	1.9E-01

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