EEG-15

ESTIMATED RADIATION DOSES RESULTING IF AN EXPLORATORY BOREHOLE PENETRATES A PRESSURIZED BRINE RESERVOIR ASSUMED TO EXIST BELOW THE WIPP REPOSITORY HORIZON—A SINGLE HOLE SCENARIO

Stephen T. Bard

Environmental Evaluation Group
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FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is minimal environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of available data concerning the proposed site, the design of the repository, its planned operation, and its long-term stability. These analyses include assessments of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

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Robert H. Neill
Director

EEG STAFF AND CONSULTANTS

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Ann Bancroft, M.A.L., Librarian

Stephen T. Bard ([1]), Ph.D., Environmental Modeler

James K. Channell, Ph.D., P.E., Environmental Engineer

Lokesh Chaturvedi, Ph.D., Engineering Geologist

Luz Elena Garcia, B.B.E., Administrative Secretary

Marshall S. Little ([1]), M.S., Health Physicist

Jack M. Mobley, B.A., Scientific Liaison Officer

Robert H. Neill, M.S., Director

Lucy G. Rubio, Secretary

Peter Spiegler ([1]) ([2]), Ph.D., Radiological Health Analyst

Norma I. Silva, Administrative Officer

S. Marc Zand, Ph.D., Hydrologist

([1]) Certified, American Board of Health Physicis

([2]) Certified, American College of Radiology

INTRODUCTION

A number of pressurized brine reservoirs have been encountered in deep drill holes which have penetrated the Castile formation of the Permian Basin (Ref. 2). Although most of these reservoirs appear to be associated with a "deformation front" within about six miles of the Capitan Reef, the Belco exploratory gas well is about three miles southwest of the center of the WIPP site while the brine encountered in the deepening of WIPP-12 (1.2 million gallon flow) is only one mile north of the site center (Figure 1). The relative close proximity of pressurized brine to the proposed site and the possibility of a potential driving force beneath the repository horizon has raised some concerns regarding the long-term integrity of the waste repository (Ref. 4).

The Environmental Evaluation Group has considered two scenarios in estimating potential radiation dose consequences which could result from future exploratory drilling for gas or oil through the sealed repository and into a pressurized brine reservoir in the Castile horizon approximately 800 feet below.

1. The EEG-11 report (January 1982) addresses a two borehole scenario in which an exploratory borehole into pressurized brine is capped, plugged and abandoned. The brine subsequently flows into the void spaces of the repository until the pressures are equalized. A second borehole at some future time again penetrates the repository allowing brine contaminated with radionuclides leached from the solid wastes to flow into a five acre holding pond at the surface.

2. This report, EEG-15, considers the potential radiation dose consequences which could result from an event similar to that which occurred following the deepening of WIPP-12. The assumption is made that only the cored wastes are brought to the surface and mixed in a one acre holding pond with the drilling mud required to penetrate down to the top of the Castile formation where pressurized brine is encountered. Although this is similar to scenario 5 addressed in the Final Environmental Impact Statement (Ref. 3) it identifies the inhalation pathway to be the most critical and not the direct exposure to a geologist examining core samples.

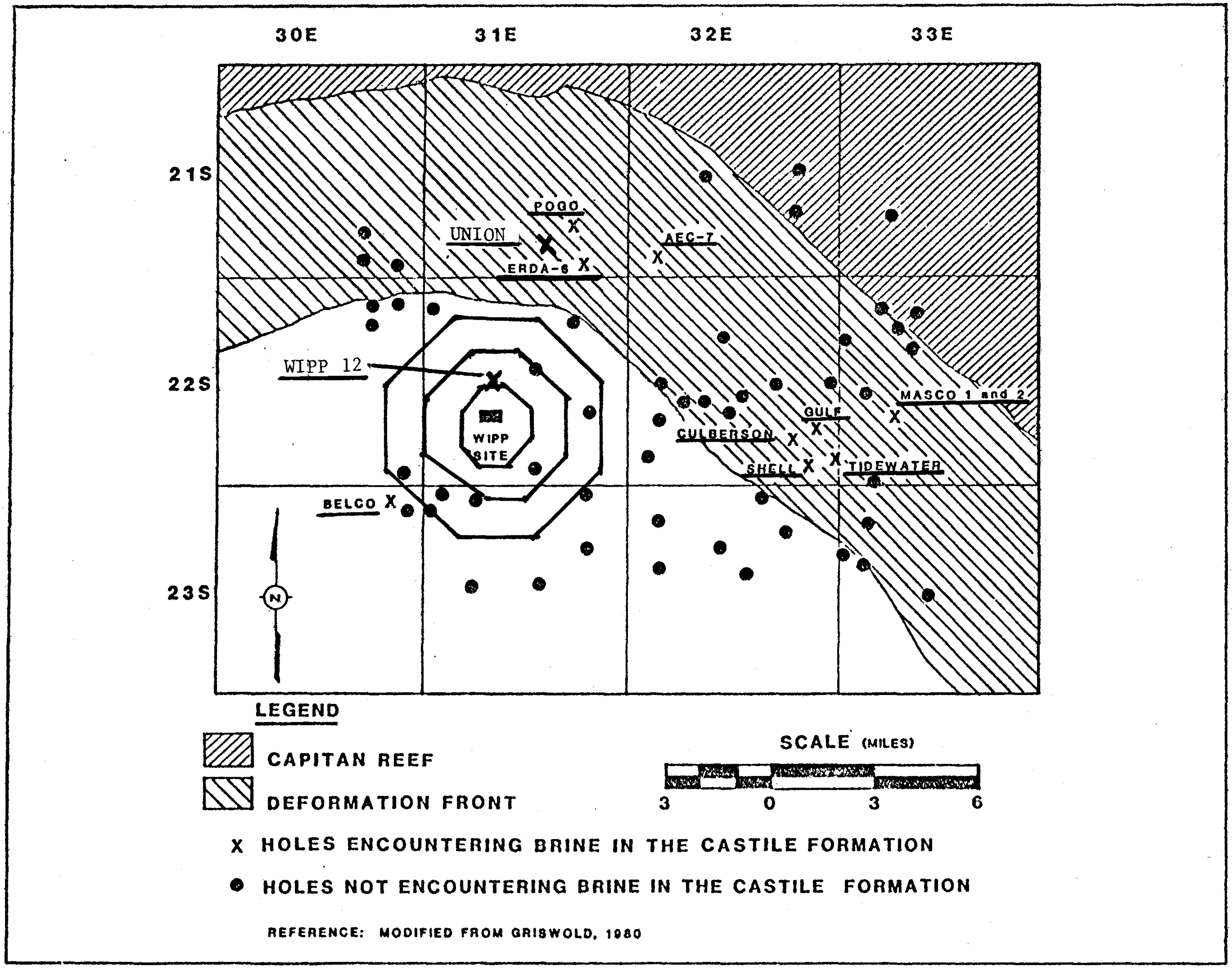

Figure 1 Location Map of Deep Boreholes in WIPP Site Vicinity

SUMMARY

A radiation dose consequence analysis has been performed for a postulated scenario in which an exploratory gas or oil well-bore penetrates the repository and intercepts a brine reservoir in the Castile formation. The brine, corings and drilling mud are contained in a one acre holding pond on the surface. Upon the completion of drilling activities the dried holding pond area is reclaimed with a bulldozer to its original topographic conformation. The estimated radiation bone dose commitments to 1) a bulldozer operator, and 2) a member of a farm family 500 meters down wind are summarized for three penetration event times in Table 1.

Table 1. Estimates of bone dose commitments from postulated brine reservoir scenario (mrem/50 years)

Penetration Time (a)	100 yrs	400 yrs	1000 yrs
On-site Exposure (b)			
Inhalation			
CH-TRU Waste	495	475	455
RH-TRU Waste	62	40	38
Off-site Exposure (c)			
Inhalation			
CH-TRU Wastes	3.9-01(d)	3.3(E-01)	3.1(E-01)
RH-TRU Wastes	5.4(E-02)	4.0(E-02)	3.8(E-02)
Ingestion			
CH-TRU Wastes	4.3(E-04)	4.0(E-04)	3.5(E-04)
RH-TRU Wastes	3.4(E-02)	6.9(E-05)	4.5(E-05)

(a) years after closure

(b) Forty hours occupational exposure to a worker reclaiming dried holding pond area.

(c) Fifty year dose commitment following a one year intake of radionuclides by a member of a farm family.

(d) log notation, 3.9(E-01) = 3.9×10^{-3}

The highest estimated 50 year bone dose commitment to an individual reclaiming the contaminated holding pond area was determined to be 590 mrem from the inhalation of CH-TRU wastes resuspended into the atmosphere at an event time of 100 years post-closure (a). A second dose model using a specific activity approach is developed in Appendix C for this same individual where an upper 50 year dose commitment of 450 mrem is calculated. Both of these derived estimates may be compared to the 5800 mrem to bone surfaces which may be expected from natural background radiation to an individual in the United States over a fifty year period (Ref. 8).

(a) Although the loss of both active and passive controls is considered a conservative assumption after 100 years it is consistent with the time frame used in the FEIS (Ref. 3) and is thus used for comparative purposes.

BRINE RESERVOIRS

Brine reservoirs are saturated solutions of salt occasionally encountered in evaporite formations. They are of concern to the rock salt mining industry since they can pose an occupational hazard to miners, particularly if they contain gases such as hydrogen sulfide, methane, nitrogen and/or carbon dioxide.

Little is known about the origin and formation of brine reservoirs. The large natural brines in the Michigan Basin that are of economic importance, and for which geochemical information is available, are believed to have resulted from a combination of factors: (1) the entrapment of the original sea water in which the evaporite layers were deposited, and (2) the percolating influx of fresh water which dissolved some of the soluble beds of salt, gypsum and carbonates (Ref. 1).

Brine reservoirs have been encountered in both the Salado and Castile formations of the Upper Delaware Basin. Those in the Salado formation which have been opened during potash mining operations are relatively small in size (maximum volume estimated at about 4500 barrels), have not contained gases and are considered to be only a minor inconvenience to mining operations (Ref. 12, p. 16). Those encountered in the Castile formation appear to be much larger and are under high pressure. Twelve brine reservoirs have been penetrated in the zone within 12 miles of the proposed WIPP site (Figure 1). Ten of these were under sufficient pressure so that brine flowed to the surface at initial rates estimated between 660 and 20,000 barrels per day (Ref. 12, p. 16). Of these ten, eight are located within a six mile wide zone bordering the Capitan Reef to the north. This zone has been referred to as the "deformation front" (Ref. 2).

The brine reservoir (Belco-Hudson), located three and one half miles southwest of ERDA #9 at the center of the WIPP site and the one more recently encountered at WIPP-12 one mile to the north are not associated with the "deformation front". Based upon the data available from WIPP-12, brine could be present directly below the repository horizon.

BRINE RESERVOIR WELL-BORE BREACH SCENARIO

General Assumptions

1. A ten inch diameter exploratory borehole penetrates the repository coring through either (a) one maximally loaded RH-TRU waste cannister, or (b) two average and one maximally loaded CH-TRU waste cannisters.

2. The cored wastes are uniformily distributed in the drilling fluids through forced circulation as drilling continues.

3. A pressurized brine reservoir is intercepted in the Castile formation 3250 feet below the surface raising the column of contaminated drilling mixture to the surface into a holding pond one acre in area and four feet deep.

4. Although exploratory drilling would most likely continue after this pressurized brine encounter, radiation dose modeling calculations are based upon ceasing operations at this point for maximum dose estimates in this scenario.

Principle Exposure Pathways to Man

1. On-site contamination

   Inhalation of resuspended contaminated soil particles by a bulldozer operator who spends a total of 40 hours reclaiming the dried holding pond to its original conformation.

2. Off-site contamination

   Ingestion and inhalation of radionuclides to members of a farm family 500 meters downwind from the reclaimed holding pond.

RADIATION DOSE CONSEQUENCE ANALYSIS

The mathematical development of radiation doses from these two pathways is given in the appendices. The dose commitments calculated for a repository breach occurring at times of 100, 400 and 1000 years post-closure are presented in Tables 2 and 3.

The highest estimated 50 year radiation dose commitment to an individual would result from the inhalation of CH-TRU waste resuspended into the atmosphere from the soil surface following reclamation of the dried holding pond. The 590 mrem maximum bone dose commitment from CH-TRU waste at 100 years is comparable to about 10% of the radiation dose to bone an individual would be expected to receive from natural background in the United States over the same 50 year period (Ref. 8).

Table 2. Estimated bone dose commitments (from inhalation) to an individual spending forty hours reclaiming a contaminated dried holding pond (mrem/50 years).

Penetration Time (years)	100	400	1000
CH-TRU waste			
Pu-(total)	475	460	450
Am-241	20	15	5
TOTAL	495	475	455
RH-TRU waste			
Pu-(total)	40	39	38
Am-241	2	1	(a)
Sr-90	20	(a)	(a)
TOTAL	62	40	38

(a) less than 1 mrem

Table 3. Estimated bone dose commitments (from one year's ingestion and inhalation) to a member of a farm family 500 meters downwind from the reclaimed holding pond (mrem/50 years).

Penetration time (years)	100	400	1000
a. CH-TRU waste			
Inhalation	3.9(E-01)[(a)]	3.3(E-01)	3.1(E-01)
Ingestion	4.3(E-04)	4.0(E-04)	3.5(E-04)
TOTAL	3.9(E-01)	3.3(E-01)	3.1(E-01)
b. RH-TRU waste			
Inhalation	5.4(E-02)	4.0(E-02)	3.8(E-02)
Ingestion	3.4(E-02)	6.9(E-05)	4.5(E-05)
TOTAL	8.8(E-02)	4.0(E-02)	3.8(E-02)

(a) Log notation, 3.9×10^{-1}

APPENDIX A

ON-SITE DOSE COMMITMENTS FROM INHALATION

Primary Contamination: The WIPP Safety Analysis Report (Ref. 15) considered the direct handling of cored wastes by a geologist to be representative of the maximum credible exposure (gamma) to an individual member of an exploratory drilling crew, however, the scenario analyzed in this document considers the potential radiation dose commitment from inhalation to a bulldozer operator who reclaims the contaminated dried drilling mud pond area.

I. Specific Assumptions and Parameters

A. A 10 inch well-bore penetrates a 7.9 ft. section (three stacked containers) of CH-TRU waste or 2 feet of RH-TRU waste.

B. The radionuclide concentrations (Ci/liter) of these wastes as a function of time to 1000 years (Tables A-3 and A-4).

C. Resuspension factor from reclaimed soil surface to air, 5×10^{-7} m^{-1}, based upon mechanical disturbance (Ref. 9).

D. A bulldozer operator spends a total of 40 hours reclaiming the dried holding pond area.

E. The dried contents of holding pond (including cored radioactive wastes) are uniformly mixed with surrounding backfill in a one acre pond 4 feet deep.

F. Depth of soil which can resuspend to the atmosphere, 1cm.

G. Occupational breathing rate, $1.2m^3/hr$ (Ref. 10).

H. Inhalation dose conversion factors (DCF), 50 year dose commitment from a single intake (Ref. 6).

II. Transport Kinetics to Man

A. Quantity of radionuclides cored and brought to the surface holding pond, Q_i(Ci)

$$Q_i = kz\pi r^2 C_r \qquad \text{Eq. A-1}$$

Where:

k = conversion factor, 28.3 liters/ft^3

z = thickness of waste containers cored, ft.

r = radius of drill, 0.42 ft.

C_r = concentration of specific radionuclides in RH and CH-TRU waste (from tables A-3 and A-4.)

Table A-1. Quantity of cored waste brought to the surface used in estimating radiation dose commitments from inhalation, Q_i (Ci)

Penetration Time (years)	100	400	1000
CH-TRU waste		Curies	
Pu (total)	3.12	3.00	2.9
Am-241	0.45	0.30	0.11
RH-TRU Waste		Curies	
Pu (total)	0.41	0.40	0.38
Am-241	0.06	0.04	0.02
Sr-90	30.0	-	-

B. Mobile surface contamination of nuclide, i, over 1 acre area ($4 \times 10^3 m^2$) and 1 cm. in depth.

$$\omega_i = \frac{f x Q_i}{A} \qquad \text{(Eq. A-3)}$$

Where:

ω_i = surface contamination, Ci/m^2

A = surface area contiminated, $4 \times 10^3\ m^2$

f = fraction of contaminated soil depth assumed to be mobile to wind transport, 1 cm/121 cm = 0.008

C. Radionuclide intake from inhalation following 40 hours' exposure, I_i (Ci)

$$I_i = \omega (Ci/m^2)\ 5 \times 10^{-7}\ m^{-1} \times 1.2 m^3/hr \times 40\ hrs \qquad \text{(Eq. A-4)}$$

D. Fifty year bone dose commitment from one year's inhalation, of nuclide i, D_i (mrem)

$$D_i = (I_i)\ (DCF)\ (10^{12}) \qquad \text{(Eq. A-5)}$$

Where:

DCF = 50 year integrated dose conversion factor for nuclide i, (mrem/pCi, from table B-1)

10^{12} = conversion factor from curies to picocuries (pCi/Ci)

III. Radiation Bone Dose Estimates from On-site Contamination (Inhalation)

Table A-2. Radiation dose commitment estimates to an individual reclaiming the contaminated dried holding pond area (mrem/50 years).

Penetration Time (years)	100	400	1000
CH-TRU waste			
Pu-(total)	475	460	450
Am-241	20	15	5
Total	475	475	455
RH-TRU waste			
Pu-(total)	40	39	38
Am-241	2	1	(a)
Sr-90	20	(a)	(a)
Total	62	40	38

(a) Less than 1 mrem

Table A-3[a]

Maximum Radionuclide Concentrations in RH-Waste Container Used in Dose Estimates

(Ci/liter)

Nuclide	Half-life (yrs)	100 yrs	250 yrs	400 yrs	1,000 yrs
Sr-90	28	0.95	2.3×10^{-2}	5.4×10^{-4}	(c)
Y-90	28 (b)	0.95	2.3×10^{-2}	5.4×10^{-4}	-
Cs-137	30	5.8×10^{-3}	1.8×10^{-4}	5.6×10^{-6}	-
Am-241	460	1.9×10^{-3}	1.5×10^{-3}	1.2×10^{-3}	4.5×10^{-4}
Pu-238	86	4.4×10^{-4}	1.3×10^{-4}	3.9×10^{-5}	3.8×10^{-7}
Pu-239	2.4×10^{4}	1.0×10^{-2}	1.0×10^{-2}	1.0×10^{-2}	9.9×10^{-3}
Pu-240	6.6×10^{3}	2.4×10^{-3}	2.4×10^{-3}	2.4×10^{-3}	2.2×10^{-3}
Pu-241	13	1.3×10^{-3}	4.3×10^{-7}	1.4×10^{-10}	-
Pu (total) (d)	-	1.3×10^{-2}	1.2×10^{-2}	1.2×10^{-2}	1.2×10^{-2}

(a) This data is derived from information contained in Table 3.1-4 of Ref. 15.

(b) Short-lived daughter in equilibrium with Sr-90

(c) Radioactivity reduced by decay to negligible amounts

(d) Except Pu-241 beta emitter.

Table A-4[a]

Maximum Radionuclide Concentrations in CH-Waste Container Used in Dose Estimates

(Ci/liter)[b]

Nuclide	Half-life (yrs.)	100 yrs	250 yrs	400 yrs	1,000 yrs.
Am-241	460	1.0×10^{-2}	8.2×10^{-3}	6.6×10^{-3}	2.5×10^{-3}
Pu-238	86	2.4×10^{-3}	7.2×10^{-4}	2.2×10^{-4}	2.1×10^{-6}
Pu-239	2.4×10^{4}	5.5×10^{-2}	5.5×10^{-2}	5.5×10^{-2}	5.4×10^{-2}
Pu-240	6.6×10^{3}	1.3×10^{-2}	1.3×10^{-2}	1.3×10^{-2}	1.2×10^{-2}
Pu-241	13	7.0×10^{-3}	2.35×10^{-6}		
Pu (total) (c)	-	7.0×10^{-2}	6.9×10^{-2}	6.8×10^{-2}	6.6×10^{-2}

(a) This data is drived from information in Table 3.1-2 of Ref. 15.

(b) Concentrations in average loaded containers are 0.04 of these values

(c) Except Pu-241 beta emitter

APPENDIX B

DOWNWIND DOSE COMMITMENT FROM INHALATION AND INGESTION

Secondary Contamination - In order to estimate potential off-site radiation doses to people, it is assumed that a family crop farming operation is located 500 meters downwind from the site of primary contamination in the reclaimed holding pond area. The soil surface is subject to wind erosion, and the downwind transport of radionuclides and the short-term (several years) equilibrium concentrations in the atmosphere and edible crops are calculated. These concentrations are converted to fifty year dose commitments to an individual based upon one year's intake.

I. Environmental Transport Kinetics and Specific Assumptions

A. Downwind radionuclide transport rate, Q_i

$$Q_i = \rho d_0 A \, C_s \, \lambda r \, (10^4) \qquad \text{Eq. B-1}$$

Where:

Q_i = source term, Ci/sec

ρ = soil density, 1.6 g/cm^3

d_0 = depth of soil profile which may be removed by wind erosion, 1 cm.

A = area of primary contamination, one acre ($4000 m^2$)

λ_r = soil particle resuspension rate, 10^{-11} sec^{-1} (Ref. 13)

C_s = average radionuclide concentration in dry dry soil assuming equal distribution of cored wastes, mud and backfill in one acre ponding area four feet deep, Ci/g

10^4 = conversion from m^2 to cm^2

B. Downwind radionuclide concentration in the atmosphere over farm, χ_i

$$\chi_i = (Q_i)\left(\frac{\chi}{Q}\right) \qquad \text{Eq. B-2}$$

Where:

χ_i = radionuclide concentration in air, Ci/m^3

Q_i = radionuclide source term, Ci/sec

χ/Q = Estimated atmospheric dilution factor 500 meters downwind, $3x10^{-5}$ sec/m^3 (Ref. 7)

C. Equilibrium radionuclide concentration on crops and soil surface, ω_i (Ref. 7)

$$\omega_i = \frac{(\chi_i)(V_d)}{\lambda_e} \qquad \text{Eq. B-3}$$

Where:

ω_i = areal surface contamination of radionuclides, Ci/m^2

χ_i = radionuclide concentrations in air, Ci/m^3

V_d = dry deposition velocity of atmospheric particulates onto soil and vegetative surfaces, 10^{-2} m/sec (Ref. 13, 14)

λ_e = effective removal rate of radionuclides deposited on above ground crop surfaces. Based upon a 14 day effective residence time, 5.8×10^{-6} sec.$^{-1}$.

II. Radionuclide Uptake into Member of a Farm Family from One Year Exposure, Curies

A. From inhalation:

$$Q_i = (\chi_i)\ (B.R.) \qquad \text{Eq. B-4}$$

Where:

Q_i = radionuclide body burden resulting from inhalation from one years residency on farm, Ci

χ_i = Average annual air concentration of radionuclides, Ci/m^3

B.R. = Annual breathing rate, 8000m^3 (Ref. 11)

B. From Ingestion:

$$Q_i = \frac{(\omega_i)(IR)}{D} \qquad \text{Eq. B-5}$$

Where:

Q_i = radionuclide body burden resulting from ingesting farm crops over an eight month growing season.

ω_i = areal concentration of radionuclides on crops, Ci/m^2

IR = daily ingestion rate of leafy vegetables crops, 0.18Kg (Ref. 11)

D = areal density of crops, $2kg/m^2$ (Ref. 11)

C. Fifty year bone dose commitment from one year's intake (mrem/50 years) (Resulting dose commitments are shown in Table B-2.)

$$D\ (mrem) = Q_i \times DCF \times 10^{12} \qquad \text{Eq. B-6}$$

Where:

Q_i = Radionuclide intake in one year.

DCF = Dose Commitment Factor. (Table B-1)

10^{12} = Conversion factor from Ci to pCi.

Table B-1. Fifty year adult bone dose commitment factors (DCF) mrem/pCi (Ref. 6).

Nuclides	Inhalation	Ingestion
Pu(total)	3.2	7.9×10^{-4}
Am-241	1.0	8.2×10^{-4}
Sr-90	0.012	7.6×10^{-3}

Table B-2. Fifty year bone dose commitment to a member of a farm family from (a) inhalation and (b) ingestion (mrem/50 years)

Penetration time (years)	100	400	1000
a. Inhalation			
CH-TRU waste			
Pu-(total)	3.3(E-01)[a]	3.2(E-01)	3.1(E-01)
Am-241	1.5(E-02)	1.0(E-02)	3.8(E-03)
TOTAL	3.9(E-01)	3.3(E-01)	3.1(E-01)
RH-TRU waste			
Pu-(total)	4.1(E-02)	3.9(E-02)	3.8(E-02)
Am-241	2.0(E-03)	1.3(E-03)	5.0(E-04)
Sr-90	1.1(E-02)	6.6(E-05)	(b)
TOTAL	5.4(E-02)	4.0(E-02)	3.8(E-02)
b. Ingestion			
CH-TRU waste			
Pu-(total)	3.7(E-04)	3.6(E-04)	3.4(E-04)
Am-241	5.6(E-05)	3.7(E-05)	1.4(E-05)
TOTAL	4.3(E-04)	4.0(E-04)	3.5(E-04)
RH-TRU waste			
Pu-(total)	4.6(E-05)	4.4(E-05)	4.3(E-05)
Am-241	7.4(E-06)	4.9(E-06)	1.8(E-06)
Sr-90	3.4(E-02)	2.0(E-05)	(b)
TOTAL	3.4(E-02)	6.9(E-05)	4.5(E-05)

(a) Log notation, E-01 = 10^{-1}

(b) Less than 10^{-6} mrem

APPENDIX C

BOUNDING DOSE LIMITS - A SPECIFIC ACTIVITY MODEL

Radiation consequence analyses using deterministic modeling techniques, in the absence of site specific data, must rely upon input parameters determined elsewhere and published in the literature. Micrometeorological parameters such as resuspension factors may vary by several orders of magnitude depending upon soil moisture content, vegetative cover, average wind velocity, etc.; it is important, therefore, to define some upper bounding dose limits which are unlikely to be exceeded, based upon the specific activity of the radionuclides (Ci/g) in the environmental media being considered.

In the case of a well drilling operation, the continuous circulation of drilling mud used for cooling and removing the cored material to the surface would dilute the specific activity of this waste to a fraction of what it was in the repository.

The most conservative dose assessment analysis which may be made in this scenario is to utilize a mass loading concept in which it is assumed that the specific activity of resuspended radionuclides in atmospheric particulates is the same as that in the dried and reclaimed holding pond. Although these may be unrealistic upper limit assumptions, it does provide some boundary conditions upon which to base maximum dose assessments.

I. Specific Assumptions and Parameters

   A. Atmospheric particulate concentration in respirable size range above dried holding pond during reclamation, 30×10^{-6} g/m^3
   B. Density of drilling mud, 1.76g/cm^3
   C. Volume of fluid in a 10 inch borehole 3250 feet deep (into Castile), 5×10^7 cm^3
   D. Total dry weight of clay fraction in column of drilling mud, 3.8×10^7 g

Table C-1. Specific activity of radionuclides in dried mud pond (100 years)

CH-TRU Waste	Ci/g
Pu (total)	9.2×10^{-8}
Am-241	1.2×10^{-8}
RH-TRU Waste	
Pu (total)	1.2×10^{-8}
Am-241	1.6×10^{-9}
Sr-90	7.9×10^{-7}

Table C-2. Fifty year dose commitment from forty hour inhalation (100 years)

CH-TRU Waste	mrem
Pu (total)	420
Am-241	30
Total	450
RH-TRU Waste	
Pu (total)	55
Am-241	4
Sr-90	1
Total	60

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