

APPENDIX G

TCEQ VERIFICATION CALCULATION

**ESTIMATING THE DOSE TO A WORKER DURING THE
OPERATING PERIOD FROM RADON WHILE PLACING
AND COMPACTING BY-PRODUCT WASTE**

TCEQ verification calculations for estimating dose to a resident living at the site boundary in the predominant down wind direction from the site.

A1 Airborne dust from open byproduct waste cell

Maywood waste byproduct source term with natural dust suspension from waste cell

Equations:

Dose(mrem/yr) = Air.conc(Ci/m3) x breathing.rt(m3/yr) x frac.yr.exposed x DCF.inh(mrem/Ci) x resuspension factor(m-1) x waste.conc(Ci/m3) x active depth(m)

Air.conc = Waste.source(Ci/s) x X/Q(s/m3) (offsite)

Waste.source(Ci/s) = Waste.conc(Ci/m3) x active.depth(m) x resusp.rt(1/s) x waste.area(m2)

X/Q (s/m3) = wind.freq / (2 x pi x wind.spd(m/s) x sigma.y(m) x sigma.z(m))

Parameters:

Byproduct waste volume (m3)	894,000	1,169,000	cy
Area of exposed waste (m2)	19,800	Vol. I, Figure 3.7 worst case active waste slope(288ft) x disposal area width(740ft)	
Average wind speed (m/s)	3.1	WCS weather station, avg 6.04 knots	
Active depth for suspnsn. (m)	0.001	particles > 1 mm not suspended	
Resuspension rate (1/s)	6.30E-09	10 times the DOE-HDBK-3010-94, Table 4-18, GM of NTS, Hanford, eroding field	
Inhalation rate (m3/yr)	8,400	RESRAD default	
Distance to site boundary receptor (m):	777	Stortest distance from Northern edge of waste area to the site boundary.	
Wind frequency annual avg,	0.322	Combined S, SSW, and SSE directions which may all contribute to the dose at the resident location	
Sigma-y	120	Pasquill B stability class, Cember 1996, p. 493.	
Sigma-z	103.00	Pasquill B stability class, Cember 1996, p. 494	
X/Q (s/m3)	1.34E-06	Pasquill-Gifford ground level, plume centerline. Adj for wind freq in N, NNE, NNW dirs, Bevelacqua 1999, p357.	
Fraction of yr exposed	1.000	8,760 hr/yr	

Maywood Bulk Waste	Site				Site	
	Waste Conc Ci/m3	Surface Conc Ci/m2	Boundary Air Conc Ci/m3	FGR #11 DCF-Inh. Sv/Bq	FGR #11 DCF-Inh. mrem/Ci	Boundary Dose mrem/yr
Nuclide						
Pa-231		0.00E+00	0.00E+00	3.47E-04	1.28E+12	0.00E+00
Ac-227		0.00E+00	0.00E+00	1.81E-03	6.70E+12	0.00E+00
Ra-226+D	7.89E-04	7.89E-07	1.32E-16	2.32E-06	8.58E+09	9.50E-03
Pb-214	7.89E-04	7.89E-07	1.32E-16	2.11E-09	7.81E+06	8.64E-06
Bi-214	7.89E-04	7.89E-07	1.32E-16	1.78E-09	6.59E+06	7.29E-06
Pb-210	7.89E-04	7.89E-07	1.32E-16	3.67E-06	1.36E+10	1.50E-02
Po-210	7.89E-04	7.89E-07	1.32E-16	2.54E-06	9.40E+09	1.04E-02
Ra-228+D	3.17E-03	3.17E-06	5.29E-16	1.29E-06	4.77E+09	2.12E-02
Ac-228	3.17E-03	3.17E-06	5.29E-16	8.33E-08	3.08E+08	1.37E-03
Th-228	3.17E-03	3.17E-06	5.29E-16	9.23E-05	3.42E+11	1.52E+00
Ra-224	3.17E-03	3.17E-06	5.29E-16	8.53E-07	3.16E+09	1.40E-02
Pb-212	3.17E-03	3.17E-06	5.29E-16	4.56E-08	1.69E+08	7.50E-04
Bi-212	3.17E-03	3.17E-06	5.29E-16	5.83E-09	2.16E+07	9.59E-05
Tl-208	1.14E-03	1.14E-06	1.90E-16	0.00E+00	0.00E+00	0.00E+00
Th-230	5.87E-04	5.87E-07	9.80E-17	8.80E-05	3.26E+11	2.68E-01
Th-232	3.17E-03	3.17E-06	5.29E-16	4.43E-04	1.64E+12	7.29E+00
U-234	5.87E-04	5.87E-07	9.80E-17	3.58E-05	1.32E+11	1.09E-01
U-235+D	2.70E-05	2.70E-08	4.51E-18	3.32E-05	1.23E+11	4.65E-03
Th-231	2.70E-05	2.70E-08	4.51E-18	2.37E-10	8.77E+05	3.32E-08
U-238+D	5.87E-04	5.87E-07	9.80E-17	3.20E-05	1.18E+11	9.75E-02
Th-234	5.87E-04	5.87E-07	9.80E-17	9.47E-09	3.50E+07	2.88E-05
Pa-234m	5.87E-04	5.87E-07	9.80E-17	0.00E+00	0.00E+00	0.00E+00
Projected Dose to Resident at Site Boundary (mrem/yr)						9.36E+00

A3 Radon gas from byproduct without interim cover

Doses to Resident Site Boundary during operations

Fernald Silo 1 & 2 source term

Reference for radon flux equations - NUREG/CR-3533, April 1984

Equations:

Radon.flux(pCi/m2-s) = Radium.conc(pCi/cm3) x emanation.coef x sqrt(m.decay(s-1) x diffusion.coef(cm2/s)) x 10,000 cm2/m2

Radon.source(pCi/s) = Radon flux(pCi/m2-s) x area(m2)

Air.conc.wkr(pCi/m3) = radon.source(pCi/s) / [sqrt(waste.area(m2)) x wind.speed(m/s) x vertical.mixing(m)] (box model)

Air.conc.offsite(pCi/m3) = radon.source(pCi/s) x X/Q(s/m3) (Gaussian plume)

Radon.dose(mrem/yr) = Air.conc(pCi/m3) x 0.001(m3/L) x frac.yr.exposed x dose.fctr(mrem/yr per pCi/L)

Parameters:

Ra-226 activity concentration(pCi/g)	8.47E+04	Maximum bulk waste byproduct source term, Maywood
Area of exposed waste (m2)	6,870	Vol. I, Figure 3.7 worst case interim covered area(100ft) x disposal area width(740ft)
Radon Dose Conv. Factor	46	mrem/yr per pCi/L, outdoor, 10% eq., referenc 10 CFR 20
Thickness of waste (m)	21.33	for use in RAECOM model on Wise-Uranium web site.
Average wind speed (m/s)	3.1	WCS-weather station, avg 6.04 knots

Distance to receptor (m): 777 Shortest distance from Northern edge of waste area to the site boundary.
 Wind frequency annual avg. 0.322 Combined S, SSW, and SSE directions which may all contribute to the dose at the resident location

Calculations:

Sigma-y 120 Pasquill B stability class, Cember 1996, p. 493.
 Sigma-z 103.00 Pasquill B stability class, Cember 1996, p. 494
 X/Q (s/m3) 1.34E-06 Pasquill-Gifford ground level, plume centerline. Adj for wind freq in N, NNE, NNW dirs, Bevelacqua 1999, p357.
 Fraction of yr exposed 1.000 8,760 hr/yr
 Radon flux (pCi/m2-s) 2.84E+04 using RAECOM model from Wise-Uranium web site
 Radon source (pCi/s) 1.95E+08
 Air conc. Site Boundary (pCi/m3) 2.61E+02

Projected Dose to Resident at Site Boundary (mrem/yr) 1.20E+01

A3b Radon gas from byproduct waste with interim cover

Doses to Resident Site Boundary during operations
 Fernald Silo 1 & 2 source term
 Reference for radon flux equations - NUREG/CR-3533, April 1984

Equations:

Radon.flux(pCi/m2-s) = Radium.conc(pCi/cm3) x emanation.coef x sqrt(m.decay(s-1) x diffusion.coef(cm2/s)) x 10,000 cm2/m2
 Radon.source(pCi/s) = Radon flux(pCi/m2-s) x area(m2)
 Air.conc.wkr(pCi/m3) = radon.source(pCi/s) / [sqrt(waste.area(m2)) x wind.speed(m/s) x vertical.mixing(m)] (box model)
 Air.conc.offsite(pCi/m3) = radon.source(pCi/s) x X/Q(s/m3) (Gaussian plume)
 Radon.dose(mrem/yr) = Air.conc(pCi/m3) x 0.001(m3/L) x frac.yr.exposed x dose.fctr(mrem/yr per pCi/L)

Parameters:

Ra-226 activity concentration(pCi/g) 8.47E+04 Maximum bulk waste byproduct source term, Maywood
 Area of exposed waste (m2) 6,870 1/4 of a cell exposed
 Radon Dose Conv. Factor 46 mrem/yr per pCi/L, outdoor, 10% eq., reference 10 CFR 60
 Thickness of waste (m) 21.33 for use in RAECOM model on Wise-Uranium web site.
 Average wind speed (m/s) 3.1 WCS weather station, avg 6.04 knots
 Distance to receptor (m): 777 Shortest distance from Northern edge of waste area to the site boundary.
 Wind frequency annual avg. 0.31 Combined S, SSW, and SSE directions which may all contribute to the dose at the resident location

Calculations:

Sigma-y 120 Pasquill B stability class, Cember 1996, p. 493.
 Sigma-z 103.00 Pasquill B stability class, Cember 1996, p. 494
 X/Q (s/m3) 1.29E-06 Pasquill-Gifford ground level, plume centerline. Adj for wind freq in N, NNE, NNW dirs, Bevelacqua 1999, p357.
 Fraction of yr exposed 1.000 8,760 hr/yr
 Radon flux (pCi/m2-s) 1.65E+03 using RAECOM model from Wise-Uranium web site
 Radon source (pCi/s) 1.13E+07
 Air conc. Site Boundary (pCi/m3) 1.52E+01

Projected Dose to Resident at Site Boundary (mrem/yr) 6.98E-01

S3 External radiation from offsite soil (contaminated by dust deposition)

Doses to Site Boundary & Nearest Resident during operations
 Maywood waste is the source term, natural wind suspension of dust, like Pathway A1

Equations:

Dose(mrem/yr) = Ground.conc(Ci/m2) x frac.yr.exposed x DCF.surf(mrem/yr per Ci/m2)
 Ground.conc(Ci/m2) = Air.conc(Ci/m3) x deposition.velocity(m/s) x time(s)
 Air.conc = Waste.source(Ci/s) x X/Q(s/m3) (offsite)
 Waste.source(Ci/s) = Waste.conc(Ci/m3) x active.depth(m) x resusp.rt(1/s) x waste.area(m2)
 X/Q (s/m3) = wind.freq / (pi x wind.spd(m/s) x sigma.y(m) x sigma.z(m))

Parameters:

Bulk waste volume (m3) 894,000 1,169,000 cy
 Area of exposed waste (m2) 19,800 1/8 of a cell exposed
 Average wind speed (m/s) 3.1 WCS weather station, avg 6.04 knots
 Active depth for suspnsn. (m) 0.001 particles > 1 mm not suspended
 Resuspension rate (1/s) 6.30E-09 DOE-HDBK-3010-94, Table 4-18, GM of NTS, Hanford, eroding field
 Dust deposition velocity (m/s) 0.01 EPA, typical
 Inhalation rate (m3/yr) 8,400 RESRAD
 Deposition time (s) 3.156E+07 1 year
 Unit conversion 1.168E+23 converts Sv-m2/Bq-s to mrem-m2/Ci-yr
 Distance to receptor (m): 777
 Wind frequency annual avg. 0.322

Calculations:

Sigma-y 120 Pasquill B stability class, Cember 1996, p. 493.
 Sigma-z 103.00 Pasquill B stability class, Cember 1996, p. 494

X/Q (s/m3) 1.34E-06 Pasquill-Gifford ground level, plume centerline. Adj for wind freq in N, NNE, NNW dirs, Bevelacqua 1999, p357.
 Fraction of yr exposed 1.000 8,780 hr/yr

Weywood Bulk Waste	Bulk Conc	Surface Conc	Site	Site	FGR #12 DCF-surf. Sv-m2/Bq-s	Site
			Boundary Air Conc	Boundary Grnd Con		Boundary Dose
Radionuclide	Cl/m3	Cl/m2	Cl/m3	Cl/m2		mrem/yr
Ra-226	7.89E-04	7.89E-07	1.32E-16	4.16E-11	6.44E-18	3.13E-05
Pb-214	7.89E-04	7.89E-07	1.32E-16	4.16E-11	2.44E-16	1.18E-03
Bi-214	7.89E-04	7.89E-07	1.32E-16	4.16E-11	1.41E-15	6.85E-03
Pb-210	7.89E-04	7.89E-07	1.32E-16	4.16E-11	2.48E-18	1.20E-05
Po-210	7.89E-04	7.89E-07	1.32E-16	4.16E-11	8.29E-21	4.02E-08
Ra-228+D	3.17E-03	3.17E-06	5.29E-16	1.67E-10	0.00E+00	0.00E+00
Ac-228	3.17E-03	3.17E-06	5.29E-16	1.67E-10	9.28E-16	1.81E-02
Th-228	3.17E-03	3.17E-06	5.29E-16	1.67E-10	2.35E-18	4.58E-05
Ra-224	3.17E-03	3.17E-06	5.29E-16	1.67E-10	9.57E-18	1.87E-04
Pb-212	3.17E-03	3.17E-06	5.29E-16	1.67E-10	1.43E-16	2.79E-03
Bi-212	3.17E-03	3.17E-06	5.29E-16	1.67E-10	1.79E-16	3.49E-03
Tl-208	1.14E-03	1.14E-06	1.90E-16	6.01E-11	2.98E-15	2.09E-02
Th-230	5.87E-04	5.87E-07	9.80E-17	3.09E-11	7.50E-19	2.71E-06
Th-232	3.17E-03	3.17E-06	5.29E-16	1.67E-10	5.51E-19	1.07E-05
U-234	5.87E-04	5.87E-07	9.80E-17	3.09E-11	7.48E-19	2.70E-06
U-235	2.70E-05	2.70E-08	4.51E-18	1.42E-12	1.48E-16	2.46E-05
Th-231	2.70E-05	2.70E-08	4.51E-18	1.42E-12	1.85E-17	3.07E-06
U-238	5.87E-04	5.87E-07	9.80E-17	3.09E-11	5.51E-19	1.99E-06
Th-234	5.87E-04	5.87E-07	9.80E-17	3.09E-11	8.32E-18	3.01E-05
Pa-234m	5.87E-04	5.87E-07	9.80E-17	3.09E-11	1.53E-17	5.53E-05

Projected Dose to Resident at Site Boundary (mrem/yr) 5.37E-02

W2. Surface water transport of ground-deposited dust to a low-lying area
 Based on ground deposited dust in Pathway S3

Operational time, Byproduct 30 yr

Projected Dose to Resident at Site Boundary over 30 year buildup time (mrem/yr) 1.61E+00

TOTAL DOSE DUE TO ALL PATHWAYS	Pathway	Dose Summary (mrem/yr)
Airborne dust from open byproduct waste cell	A1	9.36
Radon gas from uncovered active waste slope	A3a	12.00
Radon gas from byproduct waste with interim cover	A3b	0.70
External radiation from offsite soil (contaminated by dust deposition)	S3	0.05
Surface water transport of ground-deposited dust to a low-lying area	W2	1.61

TOTAL PROJECTED DOSE TO RESIDENT AT SITE BOUNDARY 23.72