CAMECO RESOURCES
CROW BUTTE OPERATION

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September 25, 2015

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Attn: Document Control Desk, Director
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Source Materials License SUA-1534
Response to License Condition 11.16

Dear Director:

By letter dated November 5, 2014, the U.S. Nuclear Regulatory Commission renewed Source Material License SUA-1534 issued to Crow Butte Resources, Inc., Crow Butte Uranium In-Situ Recovery Project, Dawes County, Nebraska (TAC J00555).

License Condition 11.16 indicated that the licensee shall provide for NRC written verification additional information on its Wellfield Decommissioning Plan for Crow Butte Uranium Project, dated June 2004, regarding the ability to detect radionuclides other than radium. Specifically, the licensee shall provide a technical basis for applying the gamma action level derived from radium to radionuclides other than radium and provide background levels that will be utilized for radionuclides other than radium (e.g. uranium).

On December 19, 2014, Crow Butte submitted the Soil Uranium Limits Plan for Crow Butte Resources, Inc. The version of this RESRAD analysis was dated August 20, 1999. A more recent analysis was completed in June 2004 using RESRAD 6.22 for Windows.

The Soil Uranium Limit Plan describing the modeling and assumptions made by Crow Butte Resources, Inc. to derive a standard for uranium in soil for the Crow Butte Uranium Project was re-submitted on September 14, 2015 with an incorrect Attachment #1. The correct attachment is being submitted with this correspondence. A complete copy of the RESRAD analysis can be found in Appendix B of the May 12, 2009 RAI response (ML091470116).

NMSS 01

If there are any further questions or concerns feel free to contact me at (308) 665–2215 ext. 114.

Sincerely,

Larry Teahon

Larry Teahon
SHEQ Manager

Enclosure

cc: Deputy Director
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Wellfield Decommissioning Plan

for

Crow Butte Uranium Project

Appendix A

Radium Benchmark Dose Assessment

Radium Benchmark Dose Assessment

A.1 Introduction

On April 12, 1999, the U.S. Nuclear Regulatory Commission (NRC) issued a Final Rule (64 FR 17506) that requires the use of the existing soil radium standard to derive a dose criterion for the cleanup of byproduct material. The amendment to Criterion 6(6) of 10 CFR Part 40, Appendix A was effective on June 11, 1999. This "benchmark approach" requires that NRC licensees model the site-specific dose from the existing radium standard and then use that dose to determine the allowable quantity of other radionuclides that would result in a similar dose to the average member of the critical group. These determinations must then be submitted to NRC with the site reclamation plan or included in license applications. This Appendix documents the modeling and assumptions made by Crow Butte Resources, Inc. (CBR) to derive a standard for U-nat in soil for the Crow Butte Uranium Project.

Concurrent with publication of the Final Rule, NRC published draft guidance (64 FR 17690) for performing the benchmark dose modeling required to implement the final rule. Final guidance (NRC, 2003) was published as Appendix E to the Standard Review Plan for In Situ Leach License Applications (NUREG-1569). This guidance discusses acceptable models and input parameters. This guidance, guidance from the RESRAD Users Manual (ANL, 2001), and site-specific parameters were used in the modeling as discussed in the following sections.

A.2 Determination of Radium Benchmark Dose

RESRAD Version 6.22 computer code was used to model the Crow Butte site and calculate the annual dose from the current radium cleanup standard. A sensitivity analysis was run for each input parameter that was not based upon local data.

The following supporting documentation for determination of the radium benchmark dose is attached:

- The RESRAD Data Input Basis (Attachment 1) provides a summary of the modeling performed with RESRAD and the values that were used for the input parameters. A discussion of the sensitivity analysis for each parameter is also included. The sensitivity analysis indicated that many of the parameters had little, if any, effect on the maximum dose. The parameters that had a noticeable affect on the maximum dose included the distribution coefficient (K_d) for each radionuclide; the soil density in the contaminated zone; the external gamma shielding factor; the fruit, vegetable and grain consumption rate; the leafy vegetable consumption rate; and the depth of roots. Each of these parameters, the sensitivity analysis and the chosen input value are discussed.
- Selected graphs produced with RESRAD that present the results of the sensitivity analysis performed on the input parameters are attached (Attachment 2).
- A full printout of the final RESRAD modeling results for the resident farmer scenario with the chosen input values is attached (Attachment 3). The printout provides the modeled maximum annual dose for calculated times for the 1,000-year time span and provides a breakdown of the fraction of dose due to each pathway.
- Graphs produced by RESRAD in Attachment 4 provide the modeling results for the maximum dose during the 1,000 year time span. A series of graphs depicts the summed dose for all pathways and the component pathways that contribute to the total dose. Additional graphs show the soil concentration and the dose to source ratio over time for each radionuclide.

The maximum dose from Ra-226 contaminated soil at the 5 pCi/g cleanup standard level, as determined by RESRAD, for the residential farmer scenario was 42.4 mrem/yr. This dose was based upon the 5 pCi/g above background surface (0 to 6-inch) Ra-226 standard and was noted at time, t = 0 years. This dose was used to determine the U-nat soil standard for use at Crow Butte as described in the following section.

A.3 Determination of Natural Uranium Soil Standard

RESRAD was used to determine the concentration of U-nat in soil distinguishable from background that would result in a maximum dose of 42.4 mrem/yr. The method involved modeling the dose from a set concentration of U-nat in soil. This dose was then compared to the radium benchmark dose and scaled to arrive at the maximum allowable U-nat concentration in soil.

For ease of calculations, a preset concentration of 100 pCi/g U-nat was used for modeling the dose. The fractions used were 48.9 percent (or pCi/g) U-234, 48.9 percent (or pCi/g) U-238 and 2.2 percent (or pCi/g) U-235. The distribution coefficients that were selected for each radionuclide were based upon the local soil types. All other input parameters were the same as those used in the Ra-226 benchmark modeling. A sensitivity analysis was conducted of the hydraulic conductivity and other parameters of the unsaturated zone and compared to the baseline case. The results showed no affect on the dose. The RESRAD output showing the input parameters is provided in Attachment 5.

Using a U-nat concentration in soil of 100 pCi/g, RESRAD determined a maximum dose of 7.9 mrem/yr. at time, t = 0 years. The printout of the RESRAD data summary is provided in Attachment 5.

To determine the uranium soil standard, the following formula was used:

$$\text{Uranium Limit} = \left(\frac{100\ \text{pCi/g natural uranium}}{7.9\ \text{mrem/yr. natural uranium dose}} \right) \text{x } 42.4\ \text{mrem/yr radium benchmark dose}$$

$$\text{Uranium Limit} = 537\ \text{pCi/g natural uranium}$$

The U-nat limit is applied to soil cleanup with the Ra-226 limit using the unity rule. To determine whether an area exceeds the cleanup standards, the standards are applied according to the following formula:

$$\left(\frac{\text{Soil Uranium Concentration}}{\text{Soil Uranium Limit}}\right)+\left(\frac{\text{Soil Radium Concentration}}{\text{Soil Radium Limit}}\right)<1$$

This approach will be used at the Crow Butte site to determine the radiological impact on the environment from releases of source and byproduct materials.

A.4 References

ANL, 1993. *"Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil"*, Argonne National Laboratory (for the U.S. Department of Energy), ANL/EAIS-8, 1993. ." Environmental Assessment Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

ANL, 2001. C. Yu, A. J. Zielen, J.-J. Cheng, D. J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo III, W. A. Williams, and H. Peterson." *User's Manual for RESRAD Version 6.*" Environmental Assessment Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

CBR, 1995. "Application for Renewal of USNRC Source Materials License SUA-1534." December 1995. Crow Butte Resources, P. O. Box 169, Crawford, Nebraska 69339-0169.

NRC, 1992. *"Residual Radioactive Contamination from Decommissioning,"* NUREG/CRR-5512 (PNL-7994) Vol. 1, U.S. Nuclear Regulatory Commission, Washington, D. C. 20555

NRC, 1999. NUREG/CR-5512, Vol. 3. "Residual Radioactive Contamination From Decommissioning. Parameter Analysis". Draft Report for Comment. October 1999. U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Washington, DC 20555-0001

NRC, 2001b. NUREG/CR-5512, Vol. 2. "Residual Radioactive Contamination From Decommissioning. User's Manual," draft, April 2001. U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Washington, DC 20555-0001

NRC, 2003. *"Standard Review Plan for In situ Leach Uranium Extraction License Applications."* NUREG-1569. Division of Fuel Cycle Safety and Safeguards, Office of Nuclear Material Safety and Safeguards, U. S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

Radium Benchmark Dose Assessment

Attachment 1

RESRAD Data Input Basis
Parameters

RESRAD Data Input Basis

Parameters

This document summarizes the data input and modeling scenario that was used to determine the radium benchmark dose for the Crow Butte Project well fields near Crawford, Nebraska. The modeling was performed using RESRAD for Windows Version 6.22 developed by the Environmental Assessment Division at Argonne National Laboratory.

Two possible scenarios for future land having the highest maximum dose to the most critically affected individual were evaluated:

1. The resident farmer scenario where an indoor occupancy time factor of 50% and an outdoor occupancy time factor of 25% is recommended (NRC, 2003).

2. The work at home scenario where a 70% factor for indoor occupancy and a 15% factor for outdoors occupancy is recommended (NRC, 2003).

The scenarios were run using RESRAD after all other parameters in the model were set and a sensitivity analysis had been run. The scenarios were then run with all other factors held constant.

The working at home scenario resulted in a slightly higher maximum dose of 43.0 mrem/year at time = 0 years compared with the resident farmer scenario which resulted in a dose of 42.4 mrem/year at time = 0 years. The resident farmer scenario is, however, the most likely future use of the land within the Crow Butte permit area. Therefore, this scenario was used to determine the radium benchmark dose. The use of the lower maximum dose value will result in a slightly lower uranium soil concentration and thus be conservative.

The following sections describe the data parameters that were used to model site-specific conditions. Where a sensitivity analysis was run on a particular factor, the results are noted.

The data input was based upon four principal sources:

1. The RESRAD Data Collection Handbook (ANL, 1993)

2. The RESRAD Users' Manual (ANL, 2003)

3. The NUREG-1569

4. Crow Butte Resources, Inc. License Renewal Application (LRA) CBR, "Application for Renewal of USNRC Radioactive Source Materials License SUA-1534,"December 1995.

Soil Concentration

1. Lead 210: Used 5.0 pCi/g per the NUREG-1569.

2. Radium 226: Used 5.0 pCi/g regulatory limit as basis for determining benchmark.

Distribution Coefficient (K_d) (values based upon data in RESRAD Handbook)

1. Lead 210: Used a distribution coefficient of 270 cm^3/g for sandy soil based upon soil type at the mine. The RESRAD User's Manual specifies the following values:

    - Sand = 270
    - Loam = 16,000

Sensitivity analysis indicates with a multiple of 100, no appreciable impact on maximum dose using higher K_d. Used values of 2.7, 270 (mid range), and 27,000 which covers the range of potential values at the site based upon sandy and loamy soil types. Graph attached.

2. Radium 226: Used a distribution coefficient of 500 cm^3/g for sandy soil based upon soil type at the mine. The RESRAD User's Manual specifies the following values:

    - Sand = 500
    - Loam = 36,000

Sensitivity analysis indicates with a multiple of 100, no appreciable impact on maximum dose using higher K_d. Used values of 5, 500 (mid range), and 50,000 which covers the range of potential values at the site based upon sandy and loamy soil types. Graph attached.

Contaminated Zone

1. Area: Used default value of 10,000 square meters.

Sensitivity analysis was performed with a 2 multiple (5,000, 10,000 and 20,000 square meters). There was no impact on maximum dose. Graph attached.

2. Thickness: 15 cm (6 inches) based upon regulatory requirement (minimum in RESRAD Handbook)

3. Length parallel to aquifer flow: Default of 100 meters was used and is based upon the square root of a 10,000 square meter contaminated zone.

Sensitivity analysis was performed with a multiple of 5 (20, 100 and 500 square meters). There was no impact on maximum dose. Graph attached.

Cover and Contaminated Zone

1. Cover depth: 0 inches (in accordance with NUREG-1569).

2. Density of contaminated zone: Used the default value of 1.5 g/cc, which corresponds to sandy soil in the RESRAD Handbook. This compares with the soil types at Crow Butte and the engineering data in the Dawes County Soil Survey.

Sensitivity analysis was run using a factor of 1.5 (i.e., 1, 1.5, 2.25) and resulted in changes in the maximum dose with a higher dose projected with a higher density. See graph. However, the standard range given in the Handbook is 1.1 to 1.6 g/cc. 1.5 is the most representative density of the soil types at Crow Butte based upon the Soil Survey as discussed in CBR, 1995.

3. Contaminated zone erosion rate: Used the default value of 0.001 meters/year. NUREG-1569 states that the erosion rate should be lower at uranium recovery sites due to the semi-arid environment. The RESRAD Handbook states that this value should be adequate for screening purposes. It also states that, while water erosion is the primary factor, wind erosion can also be significant.

Sensitivity analysis was run using a multiple of 5 (i.e., 0.0002, 0.001 and 0.005). The lower erosion rate resulted in the total dose remaining at a higher level over a longer period of time. However, there was minimal impact on the maximum dose.

4. Contaminated zone total porosity: Default value of 0.4 is the same as used for the spill impact analysis and is based upon the soil types at Crow Butte and the Soil Survey engineering data.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.2, 0.4 and 0.8). The range given in the RESRAD handbook for sandy and silty soils is 0.25 to 0.53 and is covered in this sensitivity analysis. There was no impact on maximum dose.

5. Contaminated zone field capacity: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.4, 0.2 and 0.1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

6. Contaminated zone hydraulic conductivity: The range given in RESRAD handbook for silty sand is 1×10^{1} to 1×10^{4}. The soil types in the licensed area are principally Busher loamy very fine sand. The hydraulic conductivity (K_{sat}) in m/yr. given in the RESRAD Manual for loamy sand is 4.93×10^{3}. Very fine sand is given a K_{sat} of 3.0×10^{3} in the RESRAD Handbook. A midrange value of 4.0×10^{3} was chosen since site specific data is unavailable.

Sensitivity analysis was run with a multiple of 2 (i.e., 2000, 4000 and 8000 m/yr). There was no impact on maximum dose.

7. Contaminated zone b parameter: Default parameter is 5.3 for silty loam. The RESRAD Handbook and RESRAD Manual specify a value of 4.38 for loamy sand, which corresponds to the soil classification used for the hydraulic conductivity. The range from sand to loam is 4.05 to 5.39.

Sensitivity analysis was run with a multiple of 2 (i.e., 2.19, 4.38, 8.76). There was no impact on maximum dose.

8. Evapotranspiration Coefficient: The RESRAD default value is 0.5. NUREG-1569 suggests that a value of 0.6 to 0.99 for uranium recovery sites is appropriate because

they are located in a semiarid environment. For screening purposes, a mid-value (0.75) was used.

Sensitivity analysis was run with a multiple of 1.33 (i.e., 0.564, 0.75 and 0.998) which is the maximum sensitivity set by RESRAD. There was no impact on the maximum dose.

9. Wind Speed: The RESRAD default is 2 m/s. The average for the Crow Butte site is 4.3 m/s (8.4 knots). Site data was used. No sensitivity analysis was performed since this is actual site data as recommended in NUREG-1569.

10. Precipitation: The RESRAD default is 1 m/yr. The average for the Crow Butte site is 0.39 m/yr. Site data was used. No sensitivity analysis was performed since this is actual site data as recommended in NUREG-1569.

11. Irrigation Rate: The RESRAD default is 0.2 m/yr. The actual site data should be 0 m/yr. since use of irrigation is limited in Dawes County and there is no irrigated land near the mine. Sources of irrigation are expected to be limited in the future. No sensitivity analysis was performed since this is actual site data as recommended in NUREG-1569.

12. Runoff Coefficient: The RESRAD default value is 0.2. This is the value for open rolling land in the RESRAD Handbook and was used for Crow Butte. The potential range in the RESRAD handbook for the site would be 0.1 to 0.4.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.1, 0.2 and 0.4) which covers the potential range for the site. There was no impact on maximum dose.

13. Watershed Area for nearby stream or pond: The RESRAD default value is 1×10^6 m^2. Used the estimated area of the Squaw Creek watershed, which is approximately 14 sections, or 3.63×10^7 m^2.

Although this is actual data for the site, a sensitivity analysis with a multiple of 2 was run (i.e., 1.82, 3.63 and 7.26 x 10^7 m^2). There was no impact on maximum dose.

14. Accuracy: Used the default value of 0.001.

Saturated Zone

1. Density of saturated zone: Used the default value of 1.5 g/cc, which corresponds to sandy soil in the RESRAD Handbook. This compares with the soil types at Crow Butte and the engineering data in the Dawes County Soil Survey.

Sensitivity analysis was run using a factor of 1.5 (i.e., 1, 1.5, 2.25). There were no changes in the maximum dose. See graph. The standard range given in the Handbook is 1.1 to 1.6 g/cc. 1.5 is the most representative density of the soil types at Crow Butte based upon the Soil Survey as discussed in the CBR, 1995.

2. Saturated zone total porosity: Default value of 0.4 is the same as used for the spill impact analysis and is based upon the soil types at Crow Butte and the Soil Survey engineering data.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.2, 0.4 and 0.8). The range given in the RESRAD handbook for sandy and silty soils is 0.25 to 0.53 and is covered in this sensitivity analysis. There was no impact on maximum dose.

3. Saturated zone effective porosity: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 5 (i.e., 0.04, 0.2 and 1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

4. Contaminated zone field capacity: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.04, 0.2 and 1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

5. Saturated zone hydraulic conductivity: The range given in RESRAD handbook for silty sand is 1×10^{1} to 1×10^{4}. The soil types on Section 19 are principally Busher loamy very fine sand. The hydraulic conductivity (K_{sat}) in m/yr. given in the RESRAD Manual for loamy sand is 4.93×10^{3}. Very fine sand is given a K_{sat} of 3.0×10^{3} in the RESRAD Handbook. A midrange value of 4.0×10^{3} was chosen since site specific data is unavailable.

Sensitivity analysis was run with a multiple of 2 (i.e., 2000, 4000 and 8000 m/yr.). There was no impact on maximum dose.

6. Saturated zone hydraulic gradient: The default value of 0.02 was used for screening purposes.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.01, 0.02 and 0.04.). There was no impact on maximum dose.

7. Saturated zone b parameter: Default parameter is 5.3 for silty loam. The RESRAD Handbook and RESRAD Manual specify a value of 4.38 for loamy sand, which corresponds to the soil classification used for the hydraulic conductivity. The range from sand to loam is 4.05 to 5.39.

Sensitivity analysis was run with a multiple of 2 (i.e., 2.19, 4.38, and 8.76). There was no impact on maximum dose.

8. Water Table Drop Rate: The default value of 0.001 m/yr. was used for screening purposes. The site specific drop rate should be similar because there is little consumptive use of groundwater in the immediate area other than ranches that use local wells for domestic and livestock.

Sensitivity analysis was run with a multiple of 10 (i.e., 0.0001, 0.001 and 0.01). There was no impact on maximum dose.

9. Well Pump Intake Depth: The RESRAD default is 10 m. Since the depth to saturated zone is 15 meters and most local wells are completed from 60 to 80 feet, a value of 20 meters was chosen.

Sensitivity analysis was run with a multiple of 2 (i.e., 10m, 20m and 40m). There was no impact on maximum dose

10. Model for Water Transport Parameters: Used non-dispersion per NUREG-1569.

11. Well Pumping Rate: Used default of 250 m^3/yr. (66,000 gal/yr.).

Sensitivity analysis was run with a multiple of 2 (i.e., 125, 250m and 500 m^3/yr.). There was no impact on maximum dose

Unsaturated Zone

1. Unsaturated zone thickness: Used 15 meters (50 ft) per Reg.Guide-1569.

2. Density of unsaturated zone: Used 1.5 g/cc, which is similar to the saturated zone as discussed in NUREG-1569.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.75, 1.5 and 3.0 g/cc) There was no impact on maximum dose.

3. Unsaturated zone total Porosity: The default value of 0.4 is the same as used for the saturated zone as discussed in NUREG-1569.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.2, 0.4 and 0.8). The range given in the RESRAD handbook for sandy and silty soils is 0.25 to 0.53 and is covered in this sensitivity analysis. There was no impact on maximum dose.

4. Unsaturated zone effective porosity: The default value of 0.2 is the same as used for the saturated zone as discussed in NUREG-1569.

Sensitivity analysis was run with a multiple of 1.5 (i.e., 0.3, 0.2 and 0.13). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

5. Unsaturated zone field capacity: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.4, 0.2 and 0.1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

6. Unsaturated zone hydraulic conductivity: The range given in the RESRAD handbook for silty sand is 1×10^{1} to 1×10^{4}. The soil types in the licensed area are principally Busher loamy very fine sand. The hydraulic conductivity (K_{sat}) in m/yr. given in the RESRAD Manual for loamy sand is 4.93×10^{3}. Very fine sand is given a K_{sat} of 3.0×10^{3} in the RESRAD Handbook. A midrange value of 4.0×10^{3} and is the same as used for the saturated zone as discussed in NUREG 1569.

Sensitivity analysis was run with a multiple of 2 (i.e., 2000, 4000 and 8000 m/yr.). There was no impact on maximum dose.

7. Saturated zone b parameter: Used 4.28 rather than the default parameter of 5.3. The RESRAD Handbook and RESRAD Manual specify a value of 4.38 for loamy sand, which corresponds to the soil classification used for the hydraulic conductivity. The range from sand to loam is 4.05 to 5.39.

Occupancy

1. Inhalation Rate: Used default value of 8,400 m^3/yr.

2. Mass Loading for Inhalation: Default is 0.0001 g/m^3. Handbook gives a value of 0.0003 g/m^3 for agricultural generated dust loading.

Sensitivity analysis run with a multiple of 3 (i.e., 0.0001, 0.0003 and 0.0009 g/m^3) which will cover the range from the default value. There was no impact on maximum dose.

3. Exposure Duration: Used default value of 30 years.

4. Indoor dust filtration factor: Used default value of 0.4.

5. External gamma shielding factor: The RESRAD default is 0.7, which assumes that the indoor gamma radiation level is 30% lower than the outdoor gamma radiation

level. NUREG-1569 requires that a value between 0.33 and 0.55 be used. The screening level was set at 0.55. This is a value suitable for a 7-inch thick concrete slab on grade house (NUREG/CR-5512 Vol.3, p 6-25). This is representative of the thickness of the local slab or basement floor thicknesses.

Sensitivity analysis using a 1.5 multiple (i.e., 0.367, 0.55 and 0.825 resulted in a change in the maximum dose. See graph. The low range (0.367) resulted in a maximum dose of approximately 38 mrem/yr compared to a dose of 42 mrem/yr for a shielding factor of 0.55. Based upon the fact that most construction of rural homes in the local area includes a thick concrete basement floor or slab, a shielding factor of 0.55 for the Crow Butte area is justified.

6. Indoor/Outdoor Fractions: Used defaults of 0.5 indoors and 0.25 outdoors for farmer scenario and 0.7 indoors and 0.15 outdoors for the work at home scenario. As discussed above, the resident farmer scenario was chosen as the most likely land use for the foreseeable future (i.e., 200 years).

7. Shape of contaminated zone: NUREG-1569 suggests use of actual shape. However, the shape is unknown at this time. Various shapes were assumed including a rectangle having a length of up to four times the width. The results were independent of these shapes as long as the receptor was centered. When the receptor was at the edge of the area, the dose was reduced significantly as expected. A circular shape was adopted for the modeling.

Ingestion: Dietary

1. Consumption Rates:

A. Fruit, vegetable and grain: RESRAD default is 160 kg/yr. This value was used based upon EPA estimated consumption. NRC Reg. Guide 1.109 has an estimated consumption for an adult of 190 kg/yr. Screening level set at default of 160 kg/yr.

This amount is the total consumption. RESRAD adjusts for contaminated and uncontaminated fractions based upon the size of the contaminated area.

Sensitivity analysis with 1.25 factor (i.e., 152, mid of 190 and high of 237.5 kg/yr) had an impact on maximum dose. This factor covers the range for the consumption discussed in Reg. Guide 1.109. See Graph. Based upon NRC Reg. Guide 1.109, adjusted the consumption to 190 kg/yr.

B. Leafy Vegetable: Used default value of 14 kg/yr. NRC Reg. Guide 1.109 has an estimated consumption for an adult of 64 kg/yr, while NRC estimates for dose from nuclear power plants uses a consumption rate of 30 kg/yr. Screening level for total set at default of 190 kg/yr (see above entry). This amount is the total consumption. RESRAD adjusts for contaminated and uncontaminated fractions based upon the size of the contaminated area.

Sensitivity analysis was run with a multiple of 5 (i.e., 2.8, 14 and 70 kg/yr.) to cover the range of NRC estimated consumption. There was an impact on maximum dose. Based upon these results, the consumption rate was left at the default value of 14 kg/yr. for ALARA purposes.

C. Milk: No consumption of locally produced and consumed milk per NUREG-1569. Dairy operations are not prevalent in the area.

D. Meat and Poultry: Used RESRAD default value of 63 kg/yr. According to NRC Regulatory Guide 1.109 (NRC, 1977), the recommended average value for consumption of meat and poultry is 37 kg/yr for children, 59 kg/yr for teenagers, and 95 kg/yr. for adults.

Sensitivity analysis was run with a multiple of 2 (i.e., 31.5, 63 and 126 kg/yr.) which covers the range between the RESRAD default and the rates in Reg. Guide 1.109. There

was minimal impact on the maximum dose. The default consumption rate from RESRAD was used.

E. Fish/Seafood: No consumption of locally produced and consumed fish or seafood products was considered as recommended by NUREG-1569.

F. Soil ingestion: Used the RESRAD default value of 36.5 g/yr.

Sensitivity analysis was run with a multiple of 2 (i.e., 18.25, 36.5 and 73 kg/yr). There was minimal impact on the maximum dose. The RESRAD default value was chosen.

G. Drinking water intake: Used the RESRAD default of 510 l/yr. (1.4 L/d) as a screening level. This value is based upon EPA estimates of drinking water intake. The EPA (1990) has suggested that the average adult drinking water consumption rate is 1.4 L/d; the reasonable worst-case value is 2.0 L/d.

Sensitivity analysis was run with a multiple of 2 (i.e., 255, 510 and 1020 L/yr.). There was no impact on the maximum dose. The RESRAD default value was chosen.

2. Contaminated Fractions:

NUREG-1569 states that for sites with over 25 acres (10,117 square meters) of contamination, the fraction of diet from contaminated area should be assumed to be 25% (0.25). A sensitivity analysis on these parameters was not performed based upon the guidance.

A. Water: Used the default value of 1 (i.e., 100% of consumption is from contaminated well water). All current water use in rural areas around the site is from private wells and will likely continue to be in the foreseeable future.

B. Livestock Water: Used default of 1 (i.e., 100% is from contaminated water). All current water use in rural areas around the site is from private wells and will likely continue to be in the foreseeable future.

C. Irrigation Water: Used the RESRAD default of 1 (i.e., 100% is from contaminated water). All current water use in rural areas around the site is from private wells and will likely continue to be in the foreseeable future.

D. Plant food: Used 0.25 as percentage of plant food that is contaminated.

E. Meat: Used 0.25 as percentage of meat that is contaminated.

Ingestion: Nondietary

1. Consumption Rates:

A. Livestock fodder intake for meat: Used the RESRAD default of 68 kg/day.

Sensitivity analysis was run with a multiple of 2 (i.e., 34, 68, and 136 kg/d). There was no significant impact on maximum dose.

B. Livestock water intake for meat: Used the RESRAD default of 50 L/day. According to NRC Regulatory Guide 1.109 (NRC 1977), the water ingestion rate for beef cattle is 50 L/d.

Sensitivity analysis was run with a multiple of 2 (i.e., 25, 50, and 100 L/d). There was no impact on maximum dose.

C. Livestock intake of soil for meat: Used the RESRAD default of 0.5 g/day.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.25, 0.5, and 1 g/d). There was no significant impact on maximum dose.

D. Mass loading for foliar deposition: Used the same value of 0.0003 g/m^3 for agricultural generated dust loading as the inhalation parameter discussed above.

E. Depth of soil mixing layer: Used the RESRAD default of 0.15 meters.

Sensitivity analysis was run with a multiple of 3 (i.e., 0.9, 03, and 0.1 meters). There was a minimal (i.e., less than 1 mrem/yr) impact on maximum dose

F. Depth of roots: Used 0.3 meters as a screening level based upon NUREG-1569 instead of the RESRAD default of 0.9. The root depth varies for different plants. For some plants, such as beets, carrots, lettuce, and so forth, it does not extend below about 0.3 m, which is the basis of the NRC guidance. For others, such as fruit trees, the roots may extend 2 or 3 m below the surface. Tap roots for some crops (e.g., alfalfa) can extend to 5 m. Most of the plant roots from which nutrients are obtained, however, usually extend to less than 1 m below the surface. Due to the common use of grazing crops such as alfalfa in the immediate area surrounding the Crow Butte site, a sensitivity analysis was chosen that would determine the dose using the 0.3 m NRC guidance as the screening level as well as the 0.9 m RESRAD default.

Sensitivity analysis was run with a multiple of 3 (i.e., 0.1, 0.3, and 0.9 meters). There was a significant impact on the maximum dose. Assumption of a shallow root system increased the dose significantly. In a review of the exposure pathways, the plant pathway resulted in approximately 38% of the total maximum dose. The meat pathway, which would be the primary pathway affected by deeper roots such as alfalfa, accounted for approximately 1.4% of the total maximum dose. Therefore, the root depth recommended in the NRC NUREG-1569 was chosen for this parameter.

G. Groundwater fractional usage:

- Drinking water: Used the RESRAD default of 1 (i.e., 100% from well).
- Livestock water: Used the RESRAD default of 1 (i.e., 100% from well).
- Irrigation water: Used the RESRAD default of 1 (i.e., 100% from well).

Storage Times

Used the RESRAD default values for all storage times (for vegetables, meats, fodder, etc.).