CAMECO RESOURCES
CROW BUTTE OPERATION

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January 2, 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 11.11(A), 11.11(B), 11.11(C) and 11,11(D)

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 11.11 indicates that the licensee shall provide the following information for the airborne effluent and environmental monitoring program for which it shall develop written procedures for NRC written verification:

11.11(A) "Discuss how, in accordance with 10 CFR 40.65, the quantity of the principal radionuclides from all point and diffuse sources will be accounted for, verified by, surveys and/or monitoring".

Since the Crow Butte project utilizes a vacuum dryer prior to packaging to reduce the moisture in the final uranium product, the principal radionuclides released from the facility are radon and its associated daughter products. Cameco has identified three locations at the Crow Butte project that have the potential for release of radon and its daughters. These locations are the Main Plant, the Wellhouses, and, to a lesser extent, the wellfields. How the quantity of principal radionuclides released from each of these potential sources will be accounted for will be discussed in more detail.

Main Plant

NMSSD1

Emissions from the Main Plant will be determined based on the following assumptions and measurements. The total radon emission from the Main Plant will be the sum of the radon released from the tank vents of the tanks with the potential to contain significant quantities of radon plus the ambient radon in the facilities that is vented through the building's exhaust fans.

Releases of radon from vented tanks will be calculated by measuring the concentration of radon being emitted from the tank vents. Lucas cells will be used to sample the air in the vent and quantify the concentration of radon at each vent. The attached figure shows the location of the vents to be sampled with the Lucas cell. The use of scintillation cells for the measurement radon is an approved method, as outlined in Method 115 from 40 CFR 61 Appendix B. While the method describes the use of scintillation cells for underground mining and tailing piles, it can be applied to this application.

Measurements of the radon from tank vents will be performed at a minimum of once a quarter. Samples will be taken during highest predicted concentrations and will be used to determine the effluent of radon from vented tanks. To evaluate the conditions that would represent the highest concentration of radon in the vents, samples will be collected during different stages of the tank's operation. These stages will be filling, emptying, mixing and static. These samples will be collected during the first quarter after approval of this program. After the initial sampling, a single sample will be collected from each vent on a quarterly basis to represent the radon concentration in the tank vent.

Once the concentration of radon in the tank's vent is determined the quantity of radon emitted from the vent can be calculated assuming the manufacturer's flowrate (cf/min) for the ventilation fan associated with the tank vent. Fans will be assumed to be running continuously, and total releases from vented tanks will be calculated and added to total radon released from the plant.

The amount of radon in the plant air will be determined using Track Etch cups with semi-annual exposures. There will be six sample locations throughout the facility (floor exhaust vents) and these locations are depicted on the attached figure. Each semi-annual sample results from the six locations will be averaged to determine the ambient radon concentration in the facilities air. The rate of radon released from the process facility will be based on the manufactures flowrate for each of the exhaust fans. It will be assumed that the fans are operational 100% of the time which will represent the worst case.

A total radon released from the Main Plant will be calculated semi-annually based on the sum of the radon released from the tank vents and the ambient radon released as a result

of the building ventilation. This release rate will be reported semiannually in agreement with 10 CFR 40.65.

The history of particulate sampling at the Crow Butte project indicates that, as expected, there are not significant quantities of the particulate radionuclides released from the facility. Cameco proposes that for one year, the emission of particulates will be estimated based upon semi-annual isotopic analysis. The concentrations of the radionuclides reported from the analysis of the filters by an outside accredited lab will be used to calculate the quantity of the particulate radionuclides released from the facility. The exhaust fan rates that are used for the radon estimate will be used for the airborne particulate release calculations. The fans will be assumed to operate 100% of the time. Total effluents for each radionuclide will be reported on a semi-annual basis in agreement with 10 CFR 40.65. If after one year the NRC agrees that these emission rates are insignificant Cameco will submit a written request to discontinue this reporting.

Wellhouses

Radon emissions from Wellhouses will be estimated based on the following assumptions and measurements. The concentration of radon in air released from the Wellhouse will be based on radon measurements taken within the Wellhouse utilizing Track Etch cups with a six month exposure time. These average semi-annual radon concentrations will be used along with the manufacture's rating on the Wellhouse exhaust fan to determine the total radon released from the Wellhouse on a semi-annual basis. This assumes that all radon in the Wellhouse is released into the environment at a rate of the exhaust fan. The exhaust fans in the Wellhouses are operated on a continual basis.

Four productions and four restoration Wellhouses will be monitored as described above and the average radon emission per Wellhouse will be attributed to the remaining operational Wellhouses in each group. The emissions from the operational Wellhouses will be totaled on a semi-annual basis and reported in the semi-annual report consistent with the requirements of 10 CFR 40.65.

Emissions of particulate radionuclides will be estimated based upon semi-annual isotopic analysis of filters used for semi-annual air particulate in air samples in each of the Wellhouses that are monitored for radon. The Wellhouse exhaust rate will be based on the manufactures rating on the fans in the Wellhouses. The total of all of the operational Wellhouse emissions will be totaled on a semi-annual basis and reported in the semi-annual report consistent with the requirements of 10 CFR 40.65. If after one year the NRC agrees that these emission rates are insignificant Cameco will submit a written request to discontinue this reporting.

Wellfield

Injection wells have sealed well heads and the potential of radon release is minimal. Potential emission of radon in the wellfield is limited to the production wells; however this source is also minimal. The release of radon from production wells is considered to be negligible. The submersible pumps are positioned just above the production zone of the wellfield and approximately 450' to 500' below ground surface with several feet of water above them. These submersible pumps are extracting production fluids containing dissolved radon from the formation and transfer these solutions to the nearest wellhouse through a closed poly pipe line under pressure. This production fluid is the source of the radon measured in the wellhouses.

The stagnant nature of the fluid above the pump lacks the turbulence to release a significant amount of radon gas into the well bore above the fluid surface. The stagnant water in the well above the pump is raised or lowered within the well bore by atmospheric conditions or changes in pump flow rates. These minor changes in the water level in the wellbore are the only means to exhaust gases from the production wellhead. Given the small volume of gas and the low concentration of radon in this gas, the radon released from the production wells is minor when compared to the quantity released from the Main Plant and the Wellhouses. Because the production fluid is the main source of radon measured in the wellhouses, a separate reporting of radon from the production wells will not be included in the release calculations.

A potential source of radon emitted from the wellheads and piping occurs when the wellheads are opened to the atmosphere to depressurize a wellhead that has become pressurized. Because this situation is transient and very short lived, in addition to being highly localized, emissions from this situation will be measured through the use of grab samples collected with scintillation cells. Sampling of at least one well per quarter will be planned to determine the radon concentration in the gases released during depressurization of the wellhead. These samples will be collected in the airstream being vented from the well. Currently, wells are vented at nominally 50 per month. The volume of gas will be calculated based on the casing volume and well pressure. The casing volume will assume the casing diameter and the average length of the casing from ground surface to the top of the screen for each mine unit.

The other potential source of radon release from the wellfields is the unplanned releases of process fluid resulting from spills in the wellfield. The amount of radon released as a result of a spill will be estimated based on the volume of fluid released and an estimate of the radon concentration in that fluid. The concentration of radon in the fluid will be based on the calculations used to determine the radon concentration in production fluid

by the program MILDOS. While the quantity of radon released as a result of spills in the wellfields is minor this procedure will represent a conservative estimate of the radon released.

The quantity of radon released from the process facility, wellhouses, well venting, and spills will be summarized on a semi-annual basis and reported in the semiannual report consistent with the requirements of 10 CFR 40.65. If the reported radionuclide emission is significantly greater than that anticipated in the license renewal the cause of the unexpected value will be discussed in the report.

11.11(B) "Evaluate the member(s) of the public likely to receive the highest exposures from licensed operations consistent with 10 CFR 20.1302".

The Addendum to this document contains a description of MILDOS-Area modelling performed to determine the member of the public likely to receive the maximum dose. In summary, the assessment of receptor doses considered both actual and potential receptors. The actual receptors included local residents, including the nearest resident located approximately 1000 m north-east of the main plant. Potential receptors were members of the public who may be at or near the site for greater than 50 hours per year and included a delivery person and ranchers performing haying or cattle related activities. For the potential receptors an estimate was made of the hours spent at or near the site.

Based on the outputs of this assessment, the member of the public likely to receive the maximum dose is the resident located approximately 1000 m to the north-east of the plant.

This assessment will be updated annually with current meteorological data, and the results compared with the previous year's reported data. If after three years the results are not statistically different, Cameco will request that the analysis be updated on a five year basis.

11.11(C) "Discuss and identify how radon (radon-222) progeny will be factored into analyzing potential public dose from operations consistent with 10 CFR Part 20, Appendix B, Table 2".

In 10 CFR 20.1302 (1), the regulation states that it is acceptable to show compliance to public dose limits by demonstrating by measurement or calculation that the total effective dose equivalent to the individual most likely to receive the highest dose from the licensed operation does not exceed the annual dose limit. In the response to condition 11.11(B), the Edelman resident was identified as the member of the public likely to receive the

maximum dose. CBO will show compliance to this requirement for this receptor through one of the following two methods outlined below.

The first method is to perform a dose assessment using measured effluent concentrations at a monitoring location positions 30 m from the residence of the maximum receptor. In regards to radon and radon progeny dose, the dose assessment will be performed using the following equation:

$$D = DCF \sum_{i} C_i F_i T_i$$

Where:

D = annual dose (TEDE) (mrem/yr)

DCF = dose conversion factor for Rn-222 with 100% equilibrium factor with its progeny from 10 CRF 20 Appendix B - 500 mrem/hr per pCi Rn/L

C_i = annual average concentration of Rn-222 in air (pCi/L) at the receptor location

F_i = radon equilibrium factor at the receptor

T_i = occupancy factor for the receptor

In the event that a receptor is exposed in multiple locations, e.g. indoors and outdoors, applicable equilibrium and occupancy factors will be used for those locations. For this receptor, currently all exposure will be assumed to be indoors as this is the most conservative assumption. If multiple exposure locations are to be used in the future, the NRC will be notified prior to this change.

Dose conversion factor was established by taking the 10 CFR 10 Appendix B, Table 2, value for radon with daughters present in air, (1×10^{-10} uCi/mL or 0.1 pCi/L). The annual dose is 50 mrem/yr (0.5 mSv/yr). Therefore, the dose conversion factor for radon-222 with progeny at 100% equilibrium is determined as 50 mrem/yr (0.5 mSv/yr) divided by 0.1 pCi/L, or 500 mrem/yr per pCi Rn/L.

The annual radon concentration at the receptor will be determined by calculating the average net radon concentration at the receptor location based on semi-annual radon-222 measurements with track etch cups. As this is a private resident, measurements indoors on private property is not a feasible alternative. In an article published by Shiager (1974), it was shown that buildings immediately adjacent to tailing piles had indoor radon concentration in equilibrium with those found outdoors. In FSME-ISG-01 draft guidance,

it is stated as acceptable to assume that the indoor radon concentration due to licensee activities is equal to the outdoor concentration.

The equilibrium factor between radon and radon progeny is assumed to be 50% for indoor exposure. This value is based on Regulatory Guide 3.51 and NCRP 160 and is mentioned in FSME-ISG-01 draft guidance as an acceptable default for indoor equilibrium factor.

The actual occupancy factor for this receptor will be determined based on an assessment of actual residency time.

The alternate method involves use of the MILDOS-Area atmospheric dispersion code. As per the discussion on condition 11.11(A), measurements will be collected and release rates for radon will be determined for each source term. This information can be used as inputs to the MILDOS-Area model in order to determine a dose to this receptor.

11.11(D) "Discuss how, in accordance with 10 CFR 20.1501, the occupational dose (gaseous and particulate) received throughout the entire License Area from licensed operations will be accounted for, and verified by, survey and/or monitoring".

In accordance with 10 CFR 20.1501 occupational doses will be accounted for, and verified, through monitoring of exposures from (1) radon daughters, (2) airborne particulate radionuclides, and (3) external radiation. The monitoring methods will be in accordance with NRC Regulatory Guide 8.30.

Exposure to Radon and Its Daughters

The method of measurement for radon daughters is the modified Kusnetz method. The modified Kusnetz method samples are collected and analyzed as described in NRC Regulatory Guide 8.30 and at locations and frequencies described in Section 5.8.3.2 of the License Renewal Application (LRA). Inside the Main Plant, monitoring locations are selected based on an air flow study and knowledge of the locations normally occupied by the plant personnel. Additionally, wellhouses and deep disposal well (DDW) buildings will be sampled at least quarterly using the modified Kusnetz method.

Occupancy times for wellhouses and DDW buildings will be estimated from time studies which will be revaluated annually. Concentrations for radon and its daughters in the wellfield as well as outside of the Main Plant will be negligible compared to the dose limits for occupationally exposed workers and therefore it will not be used in the annual occupational dose assessment.

The dose from radon daughters will be calculated from the concentrations measured by the modified Kusnetz method, expressed as working levels and exposure times. The procedures used to calculate these doses and the methods of record keeping are described more fully in Section 5.8.4 of the LRA and in the Crow Butte Standard Operation Procedures (SOP).

Airborne particulate radionuclide concentrations will be calculated based on routine air sampling of representative Wellhouses, DDW buildings, and Main Plant. Analysis of air sampling filters within the Main Plant and the Wellhouses for U-^{nat}, Th^{230}, Ra^{226}, and Pb^{210} will be performed on a semi-annual basis. Doses assigned to the individual from particulates will be based on the results of the air particulate sampling program and the occupancy times. Non-routine work will be performed under a Radiation Work Permit (RWP) and based on the circumstances either area air particulate samples or breathing zone samples will be collected. Exposures during non-routine work will be determined from the results of the air particulate samples and the time of exposure. During some activities Personnel Protection Equipment (PPE) will be used to reduce the exposure to the employees and the appropriate protection factor will be used to calculate the actual exposure.

The procedures used to calculate exposures to airborne radionuclides and the methods of record keeping are described more fully in Section 5.8.4 of the LRA and in the Crow SOPs.

External radiation exposure will be determined by personal dosimetry or, if not issued, then as work group dose. Each work group will have at least one person assigned external monitoring dosimetry and high risk work groups, such as plant operators, will have all individuals assigned personal dosimetry. The methods of monitoring exposure to external radiation and the methods of record keeping are described more fully in Section 5.8.4 of the LRA and in the Crow Butte SOPs.

Total occupational dose or Total Effective Dose Equivalent (TEDE) to individuals will be the sum of exposures from (1) radon daughters, (2) airborne particulate radionuclides, and (3) external radiation. Occupancy factors for each area will be assigned for each work group (i.e. operators, wellfield workers, maintenance). Work performed under Radiation Work Permits will be monitored separately from the routine sampling program and the concentrations will be included in the TEDE calculation. Results will be reported to employees on an annual basis as required and summarized in the semi-annual effluent report.

If there are any further questions or concerns feel free to contact me at (308) 665–2215 ext. 112.

Sincerely,

Doug Pavlick
General Manager

Enclosure

cc: Deputy Director
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CBO- File

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Addendum

MILDOS-Area Modelling and Validation of Emissions and
Public Dose for the Crow Butte Facility

The MILDOS-Area predictive modelling software has commonly been used as part of facility licensing to predictively model emissions and doses to members of the public as part of regulatory decision making. This document provides supplemental information to the original MILDOS-Area estimate for the Crow Butte Operation. Specifically, there is an enhanced assessment of the maximally exposure member of the public and comparison of modelled outputs to actual measured airborne effluent concentrations.

1.0 Operations Summary

The following summary of operational process at Crow Butte is based upon year 2013 operations, however the process has been in this configuration since 2011.

1.1 Production Circuits

1.1.1 Down-flow IX Circuit Process Summary

Currently the Down-flow Ion Exchange Circuit consists of Mine Units 7, 9 and 11. Within a mine unit, process water, also called lixiviant, is injected in to injection wells and uranium (and radon) bearing fluid is extracted from production wells. The lixiviant is transferred through a network of pipes to the Central Processing Plant (CPP), where the water is injected in to one of three pairs of down-flow ion exchange (IX) columns. Each down-flow IX column is sealed, with water entering at the top and leaving at the bottom. As the uranium bearing water travels through the column, uranium is stripped out of the water and attaches to resin beads in a chemical reaction. Once the resin is loaded with uranium, the column is taken offline to transfer the resin to the elution columns, where the uranium is stripped off of the resin. The IX column is filled with unloaded resin, and put back online.

When the loaded resin column is taken offline, the pressure inside is released through a vent that is plumbed in to the Eluent tank, which is itself vented through the roof to atmosphere. The resin is then either transferred directly to the elution column with process water, or is first run across a resin shaker deck to clean it. When the resin runs across the shaker deck, it is moved with process water.

Each pair of down-flow columns run in a lead-lag configuration. Uranium loaded lixiviant from the mine units enter the top of the lead IX column, travels down through the resin beads, and exits the bottom of the column. This water then enters the top of the lag column, travels down through the resin beads, and exits the bottom of that column. Since more uranium will be stripped out in the lead column, the resin beads become saturated with uranium in this column before the lag, and when the loaded resin is transferred out and replaced with unloaded resin, this column becomes the lag and the other becomes the lead.

The effluent leaving each pair of down-flow IX columns contains very little uranium, and is returned to the well fields to be re-injected in to the injection wells. A 1% bleed is taken off of the effluent of each pair of columns, and is either recycled into chemical makeup or used to move resin. The process water used to move resin eventually becomes dirty and is either sent to the commercial evaporation ponds or to the deep disposal feed tank, for disposal in the deep injection well.

Since the majority of the down-flow IX circuit is closed and under pressure, radon release can only occur at certain points. The piping in the wellfields is sealed which means the potential for radon to be released from the wellfields as part our routine operations in minimal. However, if a well becomes pressurized, a bleed port is opened to relieve the pressure; radon can be vented to the atmosphere when this operation is performed. In the CPP radon will periodically be released from the columns when the loaded resin is transferred to the elution columns. Radon will also be released from the bleed water when it is used in chemical makeup, or for moving resin with final disposal in the commercial evaporation ponds.

1.1.2 Up-flow IX Circuit Process Summary

Currently the Up-flow Ion Exchange Circuit consists of Mine Units 8 and 10. Within a mine unit lixiviant is injected into injection wells, and uranium (and radon) bearing lixiviant is extracted from production wells. This lixiviant is transferred through a network of pipes to the Central Processing Plant (CPP), where it is injected in to one of two trains of up-flow ion exchange (IX) columns. Each train of up-flow columns consists of four columns, all open to atmosphere. The uranium bearing lixiviant enters the columns from the bottom, traveling up through resin beads, and is then extracted from the top. The process water from the top of the column is then injected in to the bottom of the next column in series. The barren lixiviant from the last column is then processed through backwash injection filters, and is returned to the well fields for re-injection into the injection wells. The waste water from the injection filters, from backwash cleaning cycles, is primarily delivered to a backwash tank and then to the deep injection well.

As the uranium bearing lixiviant travels through the column train, and passes over the resin beads, the majority of the uranium will be stripped out in the leading columns. When the lead column's resin beads become saturated, it is taken offline and the next column in the train becomes the lead. The offline column has its resin transferred to the resin elution column, to strip the uranium from the resin, and unloaded resin is transferred back in to the column. The column is then brought back online as the last column in the train.

As with the down-flow columns, radon may be released when the bleed value on the well heads is opened as part of remediation of a pressurized well. Since the up-flow columns are open to atmosphere, most of the radon in the lixiviant will be released there. Any radon left in the fluid, with the exception of a small amount released in the backwash waste water, will be returned to the well fields for injection back into the wells.

1.1.3 Restoration Circuit

Currently the Restoration Circuit consists of Mine Units 4, 5 and 6. Within a mine unit restoration process water is injected into injection wells, and uranium (and radon) bearing water is extracted from the production wells. The process water is transferred through a network of pipes to the Restoration Plant (RO Building), where the water is injected in to one of three pairs of restoration down-flow ion exchange (IX) columns. The process follows the same as the production down-flow IX columns, except for the column pairs servicing Mine Units 4 and 5.

Instead of the effluent going directly back to the well fields (with an approximate 1% bleed), the effluent of the columns servicing mine units 4 and 5 are passed through separate reverse osmosis filtration systems before returning to the well fields for re-injection. Additionally, the bleed from the column pair servicing mine unit 6 is processed through mine unit 5's RO system, in order to make up for waste water lost during the RO treatment. The waste water from the RO filters, approximately 25%-30% of the input, is transferred to the deep disposal feed tank, and the disposed of in the deep injection well.

As with the production down-flow circuit, the majority of the restoration circuit is closed and under pressure, and radon release can only occur at certain points. Opening of bleed valves to remediate pressurized wells is the only potential release mechanism in the wellfields. In the restoration building, radon will periodically be released from the columns when the loaded resin is transferred to the elution columns. Radon will also be released from the RO waste water. The RO waste water will be stored in the deep disposal feed tank before deep injection, during which it will release radon gas.

2.0 Model inputs and assumptions

2.1 General Information

The primary radionuclides of interest from this model are radon gas (Rn-222) and radon progeny (Po-218, Pb-214 and Bi-214), however MILDOS also calculates dose from Pb-210 and Po-210 as well. These radionuclides are part of the U-238 decay series and this decay series is assumed to be the primary source of exposure because the contribution of the U-235 decay series is less than 5% of that from the U-238 series. Primary release mechanisms for radon gas from the circuit have been discussed in the previous section. NRC's recommendation that for modern, low temperature vacuum driers the particulate release is essentially zero, as stated in NUREG 1910 (USNRC 2009), has been adopted for this model. As shown in Table 2.1-1, measurements of airborne particulate collected to date demonstrate that uranium concentrations at our environmental monitoring stations are comparable to or below background concentrations and provide basis for use of this assumption.

Table 2.1- 1: Airborne Particulate Concentrations for 2013 Above Background

	Uranium (µCi/ml)	Radium 226 (µCi/ml)	Lead-210 (µCi/ml)	Thorium-230
AM6 (background)	1E-16	1E-16	2E-14	1E-16
10 CRF 20 Effluent Concentration	9E-14 (D)	9E-13	6E-13	3E-12 (W)
AM1	0	0	0	0
AM2	1E-16	0	0	0
AM3	0	0	0	0

The transport of modelled radiological emissions from the sources is predicted using a sector-averaged Gaussian plume dispersion model. The dispersion model uses the meteorological data provided by the user and also includes mechanisms of dry deposition of particulates, re-suspension, radioactive decay and progeny in-growth and plume reflection. Deposition build-up and in-growth of radioactive progeny are considered in estimating ground concentrations.

2.2 Source Term Calculations

The radionuclide releases from the Crow Butte operation have been determined for each source of emissions. Sources addressed in this model are the wellfields, specifically the emissions from header houses and well heads resulting from venting, up-flow IX columns, down-flow IX columns and the reverse osmosis plant. These sources include emissions from both production and restoration activities. The locations of these sources have been defined within the MILDOS model based on Cartesian

coordinates relative to a reference point. In this model the reference point is central processing plant (CPP) located at 0,0.

As is discussed further in Section 2.2.5, consideration was given to whether wellfields sources were best characterized as point or area source terms. The use of area source terms was selected based on the ability to more accurately match actual measurement radon gas concentrations at our monitoring stations. Table 2.2-1 provides the location of each source. For wellfield source terms, the location represents the center of the wellfield. IX column and RO plant source terms are located at the CPP.

Table 2.2-1: Locations of Source Terms

Source Name	X - Location (km)	Y - Location (km)
MU2+3	0.057	0.103
MU4	0.223	-0.101
MU5	-0.145	0.619
MU6	-0.958	1.345
MU7	-0.028	-0.451
MU8	-1.631	2.183
MU9	0.609	-0.794
MU10	-2.621	3.02
MU11	0.921	-0.977
CPP	0	0

For the initial assessment, source emissions were calculated using guidance from NRC Regulatory Guide 3.59 (USNRC 1987). The formulas used to determine the emissions are shown below. The radon release rate from 1 m3 of rock was calculated using equation (1) and the amount of radon circulated within the lixiviant on an annual basis is calculated using equation (2).

$$G = \frac{R\rho E(1-p)}{p} x10^{6} \quad (1)$$

Where:
G =the radon release rate from $1 m^3$ of rock
R = radium content, pCi/g
ρ = the rock density, g/cm^3
E = emanating power and
p = formation porosity

$$Y = GM\epsilon D \; x \; 1.44 \quad (2)$$

Where:
Y = yearly radon release to the lixiviant, Ci/yr
M = lixiviant production rate, L/min
ε = equilibrium factor for radon ($1 - e^{-\lambda t}$ where λ = radon decay constant and t = residence time)
D = production days per year

Table 2.2-2 contains the input parameters used in determination of source terms. As data related to the magnitude of specific source terms are collected through the proposed radon emissions monitoring

program, this data can be used to refine and improve the source term estimates. For the production and restoration mine units, mine unit specific lixiviant production rates were used in the calculation of source terms. The total production lixiviant flow rate is approximately 26,500 L/min. Of this total 50 percent, coming from mine units 8 and 10, is processed by the upflow columns and 50 percent, coming from mine units 7, 9 and 11, by the downflow.

Table 2.2-2: Input parameters for MILDOS Model

Parameter	Value
Average ore grade	0.27%
Radium-226 content in ore	764 (pCi/g)
Rock density	1.89 g/cm^3
Emanating power	0.2
Formation porosity	0.29
Radon decay constant	0.181 /day
Residence time	7 days
Production days per year	365.25
Mine Unit 2 Restoration Flow Rate	133.3 L/min
Mine Unit 3 Restoration Flow Rate	120.5 L/min
Mine Unit 4 Restoration Flow Rate	979.8 L/min
Mine Unit 5 Restoration Flow Rate	816.1 L/min
Mine Unit 6 Restoration Flow Rate	606.3 L/min
Mine Unit 7 Lixiviant Flow Rate	4758 L/min
Mine Unit 8 Lixiviant Flow Rate	5971 L/min
Mine Unit 9 Lixiviant Flow Rate	4565 L/min
Mine Unit 10 Lixiviant Flow Rate	7279 L/min
Mine Unit 11 Lixiviant Flow Rate	3927 L/min

This information can be used to determine the total radon available for release. The final parameter is the radon release fraction from each source. For example, the fraction of the total radon in the lixiviant released through well venting. To determine a reasonable estimate of these release rates, a sensitivity analysis was performed in which the release rate parameters were varied and the resulting modelled radon gas concentration was compared with measured values. The parameters that produced the closest overall fit to measurements were used in this analysis. The sensitivity analysis is described in Section 2.2.5. Sections 2.2.1 through 2.2.4 include the best fit release rate parameters in the descriptions of the source terms.

2.2.1 Wellfields

Radium 226 is assumed to be in equilibrium with its parent radionuclide, U-238. At an average grade of 0.27%, the radium 226 content of the ore is 764 pCi/g. Using this value and the applicable parameters stated in Table 2.2.2, the radon release rate from 1 m3 of rock, using equation (1), is 7.05E-4 Ci/m3. Using equation (2) and the flow rate for each of the mine units, the total annual radon present within the restoration or production fluid was calculated by mine unit. The yearly radon emission for each mine unit was then determined using the assumed radon release rate of 5% within the wellfields. The radon emissions from the production and restoration wellfields are shown in Table 2.2.1-1.

Table 2.2.1-1: Radon Release Rates Calculated for Each Source

Source	Radon Release (Ci/yr)
Mine Unit 2+3	4.7
Mine Unit 4	18.0
Mine Unit 5	15.0
Mine Unit 6	11.1
Mine Unit 7	63.5
Mine Unit 8	79.7
Mine Unit 9	60.9
Mine Unit 10	97.1
Mine Unit 11	52.4
CPP (upflow IX+downflow IX+ RO)	4698.9

2.2.2 Upflow IX Columns

The lixiviant from mine units 8 and 10 is processed by the upflow IX columns at the CPP. Because these columns are open to the atmosphere, the majority of the radon present in the fluid will be degassed and released to the atmosphere. It is difficult to determine the exact percentage of radon released, therefore to be somewhat conservative in our modeling, we have assumed that 100% of the radon remaining in the lixiviant is degassed within the upflow IX columns. Table 2.2.1-1 presents the combined radon emissions from the CPP (up-flow columns, downflow columns and Reverse Osmosis).

2.2.3 Down-flow IX Columns

The lixiviant from mine units 7, 9 and 11 is processed by down-flow IX columns as well as the restoration water from mine units 4 through 6. Down-flow columns are kept under pressure until the resin beads are transferred, at which time the system is depressurized. There are a total of 7 down-flow columns and each column has its resin transferred approximately once per week. Therefore, nominally, one column is transferred per day. Though the emission from down-flow columns are not continuous, because the columns are, on average, depressurized for transfers daily this has been approximated by a continuous release, using the assumption that 20% of the radon remaining in the lixiviant is released when the system depressurizes. Table 2.2.1-1 presents the combined radon emissions from the CPP (up-flow columns, downflow columns and Reverse Osmosis).

2.2.4 Reverse Osmosis Plant

After passing through down-flow IX columns, restoration water from mine units 4 and 5 is further treated in the reverse osmosis plant. The RO system is a closed, pressurized circuit, therefore radon is not emitted from the RO plant as part of the filtration process. However, approximately 25% of the input water volume is removed as waste water. Once outside the RO system, this water is no longer under pressure and can release radon to the environment. As with the up-flow columns, it was assumed that 100% of the radon from the waste water was released. Table 2.2.1-1 presents the combined radon emissions from the CPP (up-flow columns, downflow columns and Reverse Osmosis).

2.2.5 Sensitivity Analysis

In the calculation of source terms using Regulatory Guide 3.59, the primarily variable is the percentage of available radon released to the atmosphere. The other input parameters, e.g. ore body grade and size, water volumes, etc., are determined by physical or operational conditions. To determine the best estimate

for the radon release rate for the source terms, a sensitivity analysis was performed in which the radon venting rate was altered and the resulting modelled radon gas concentrations were compared with the measured radon gas concentrations at those receptor points.

Measurements for the sensitivity analysis included data from 1999 – 2013 at the 6 environmental monitoring stations (AM1 – AM5 and AM8), data from 2011 – 2013 at four locations within the wellfield areas (AM22 – AM25) and from 2011 – 2013 at four wellfield header houses (WH9, WH17, WH47, WH50). Because individual data points have significant uncertainty due to both measurement uncertainty at low levels and background radon fluctuations, a statistical analysis of the data was performed in order to determine the most reasonable data for comparison to the modelled results. To determine the most appropriate concentration for background subtraction, a distribution analysis of the annual average radon results from 1999-2013 at the background station (AM6) was performed. This data set fit a lognormal distribution based on a Shapiro-Wilk test with a W=0.968 and significance level of p=0.82. The geometric mean of the distribution of background radon results was 0.48x10-9 μCi/ml. This geometric mean background was subtracted from the annual average radon concentration measured at each station for each of the years stated earlier. Finally, for each location, the median background subtracted radon concentration was calculated over the 1999-2013 time period. Table 2.2.5-1 shows median radon concentrations calculated from measurements for each location.

Table 2.2.5-1: Median Radon Gas Concentrations for Comparison with Modelled Results

Monitoring Location	Median Radon Gas Concentration (pCi/m^3)
AM-1	0
AM-2	215
AM-3	0
AM-4	15
AM-5	315
AM-8	165
AM-22	115
AM-23	565
AM-24	315
AM-25	1065
WH-9	515
WH-17	415
WH-50	0
WH-47	115

The parameters considered in the sensitivity analysis were the radon release rate in the wellfields and the downflow IX columns. Because both the upflow IX columns and RO storage tank are open to the atmosphere, they are likely to be highly degassed. Therefore the release rate for both sources was left at 100% (1.0). In addition, the use of point and area source terms for the wellfields was assessed. The predicted radon gas concentrations at each of the measurement points was compared to the mean radon concentrations in Table 2.2.5-1 determined from measurement data. Two non-parametric statistical tests, the Sign Test and Wilcoxon Matched Pairs Test, were used to compare measured radon to predicted radon concentrations. Table 2.2.5-2 shows the variable combinations considered in this assessment and the results of both statistical tests for each combination. All combinations provide statistically significant fits to the measured data, however, the best overall fit to the measurement data was an area source geometry for the wellfields with a wellfield release rate of 5%, an upflow IX release rate of 100%, a downflow IX release rate of 20% and a reverse osmosis release rate of 100%. These parameters have been used as the

starting point for the MILDOS model for Crow Butte. This information will be updated with measurement data as it becomes available.

Table 2.2.5-2: Results of Comparison of Measured Radon Gas Data to MILDOS Predictions

Wellfield Source Geometry	Radon Release Rate in Wellfields	Radon Release Rate in Downflow IX Columns	Sign Test		Wilcoxin Matched Pairs	
			Z-Value	p-Value	Z-Value	p-Value
Point Source	0.1	0.1	0.80	0.42	0.72	0.47
	0.2	0.1	1.34	0.18	1.54	0.12
	0.05	0.1	0.27	0.79	0.16	0.88
	0.01	0.1	0.27	0.79	0.16	0.88
	0.1	0.2	1.87	0.06	1.16	0.25
	0.05	0.2	0.80	0.42	0.41	0.68
Area Source	0.1	0.1	-0.27	0.79	0.41	0.68
	0.2	0.1	-0.27	0.79	0.22	0.83
	0.05	0.1	0.27	0.79	0.60	0.55
	0.01	0.1	0.27	0.79	0.41	0.68
	0.1	0.2	0.80	0.42	0.09	0.92
	0.05	0.2	0.27	0.79	0.03	0.97

2.3 Meteorological Data

Meteorological conditions influence the dispersion of radionuclides from our emission sources. This information is one of the key inputs to the MILDOS-Area program. For this assessment, the wind rose generated from data collected from May 1982 through April 1984 was utilized. In the Safety and Evaluation Report for the Crow Butte License Renewal NRC "found no technical reason for invalidating previous wind data".

2.4 Receptors

Receptors used in this assessment included the actual and potential receptors, listed in Table 2.4-1. Actual receptors are the nearby residents. Members of the public who may be at or near the site, i.e. potential receptors, included a delivery person and ranchers performing haying and cattle ranching activities. For potential receptors, only people spending at least 50 hours per year in the vicinity of the site were considered. For each potential receptor an estimate was made of the hours spent at or near the site. The exposure time for the delivery person and the vendor were based on the assumptions shown in Table 2.4-1. This assessment assumes that it is the same delivery person and vendor that visits the site each time throughout the year, however it is likely that a different individuals will perform these roles at various time during the year. All other potential receptors in the wellfield area, e.g. drillers, are considered occupationally exposed.

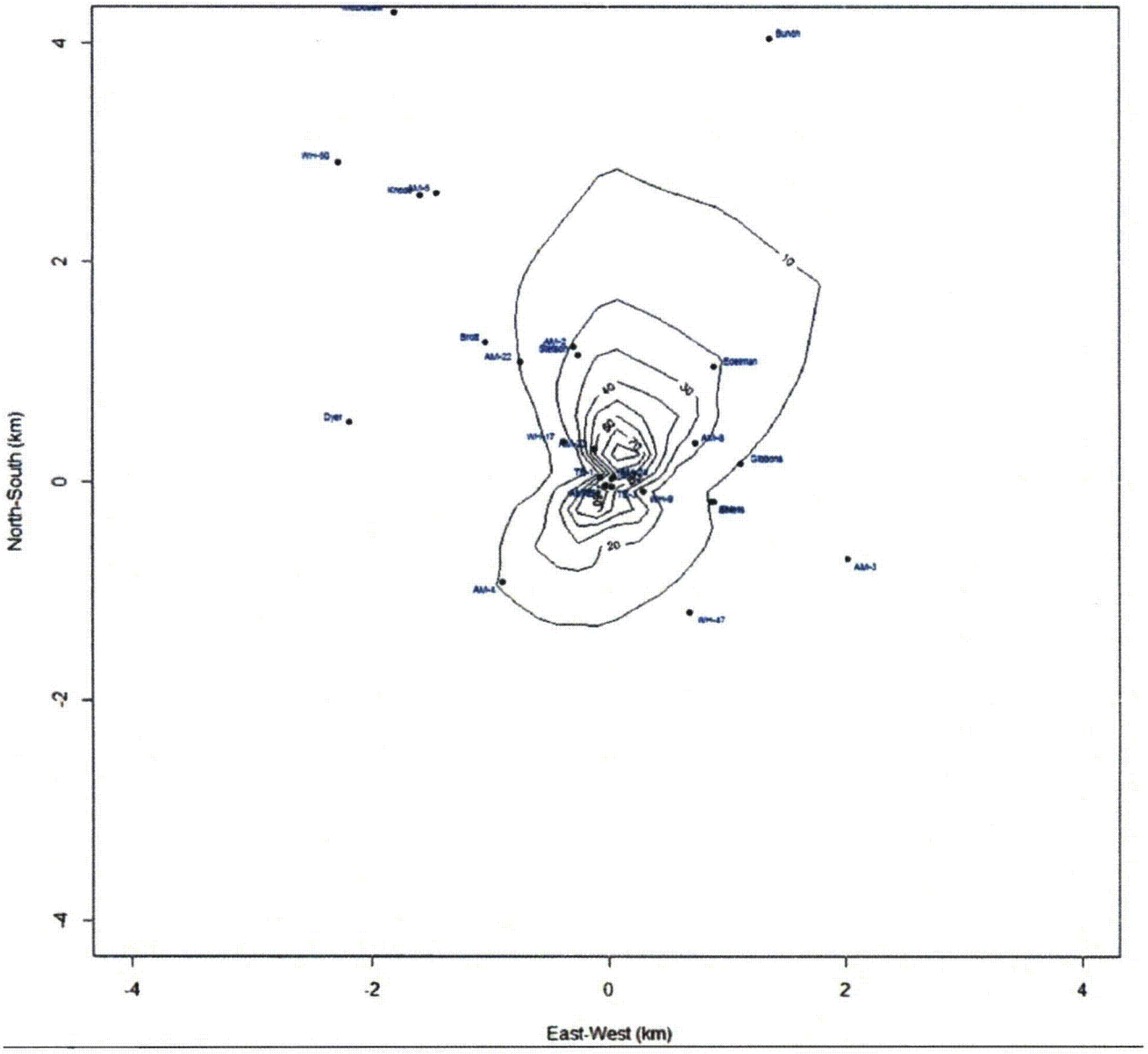
Table 2.4-1: List of Potential Receptors

Receptor Name	Annual Hours	Assumptions for Calculation
Delivery Person	130	0.5 hr/day * 5 days/week * 52 weeks/yr
Rancher - Haying	160	8 hr/day * 5 days/week * 4 weeks/yr

Rancher – Cattle	416	8 hr/day * 1 day/week * 52 weeks/yr

A grid analysis was also performed in which hypothetical receptors were placed at periodically spaced locations around the CPP. Grid points were located along the cardinal coordinates at spacing's of 10m, 50m, 250m, 500m and 1000m as distance increased from the CPP. The grid analysis allows us to better visualize the dispersion plume of radon gas around the site and determine the expected location of the maximally exposed members of the public. Figure 2.4-1 presents a contour plot of radon gas concentrations, with areas of similar predicted concentration connected to produce iso-curves over the property. In this figure, the CPP is located at the origin (0,0).

Figure 2.4-1 Iso-curve of Predicted Annual Dose in mrem/year



3.0 Dose Estimates

The MILDOS-Area model was used to calculated doses to actual and potential members of the public. Resident doses were calculated based on the location of their actual residences. Delivery personnel were assumed to be located within 10m of the CPP and ranchers at least 250m from the CPP. In addition, for comparison doses were calculated at 265 locations throughout the site as part of the grid analysis, assuming a 2000 hr/yr occupancy. Four grid points were located at 10m from the CPP, but the results indicated MILDOS somewhat underestimates concentrations of radon very close to buildings. However, as part of the sampling program at the site during 2013, four sampling stations for radon gas and radon progeny located within about 10 m of the CPP, one on each side. From these locations, the maximum background subtracted radon gas and radon progeny measurements were 0.7E-9 μCi/ml and 0.0007 WL, respectively. This is essentially the same concentrations as those modelled for the grid point at 250m east and 500m north of the CPP. Using the MILDOS dose estimate for this grid point scaled by the hours per year of exposure for the delivery person, the modelled dose was 0.8mrem/yr. For the ranchers, we selected the grid point located 200m north of the CPP, which is the location with the highest predicted dose based on the grid analysis. Though this location is closer than a rancher is likely to be able to come to the operation due to restrictions to wellfield access, it provides a conservative estimate for dose. For the rancher haying the dose estimate is 2.0 mrem/yr. and for the cattle rancher it is 5.3 mrem/yr.

The maximum actual receptor dose was receptor #27 (Gibbons) at 30.6 mrem. This dose assumes full-time occupancy; however this is a conservative assumption. Dose estimates from the MILDOS model for actual receptors and environmental monitoring stations are presented in Table 3.0-1. Dose estimates for grid points are presented in Table 3.0-2.

Table 3.0-1: MILDOS Results for Actual Receptors and Environmental Monitoring Stations Based on Full-Time Occupancy

Location Name	X(KM)	Y(KM)	Dose mrem/yr (8760 hours)
AM-1	0.9	-0.13	8.98
AM-2	-0.36	1.21	18.8
AM-3	2.06	-0.59	2.67
AM-4	-0.84	-0.96	10.7
AM-5	-1.6	2.54	5.27
AM-6	-4.18	4.57	0.979
AM-8	0.72	0.4	25.4
AM-22	-0.81	1.05	8.56
AM-23	-0.13	0.29	51.8
AM-24	0.04	0.04	27.6
AM-25	-0.03	-0.04	37.2
TE-1	-0.06	0.04	17.7
TE-2	0.02	0.02	3.71
TE-3	0.03	-0.04	19.4
TE-4	0	-0.03	6.47
WH-9	0.3	-0.06	22.6
WH-17	-0.4	0.35	12.6
WH-50	-2.44	2.78	3.11
WH-47	0.75	-1.14	8
TCA-1	-8.27	-2.15	0.496
TCA-2	-8.18	-2.72	0.519
TCA-3	-8.72	-0.87	0.399
TCA-4	-8.07	-1.7	0.494
TCA-5	-10.89	-1.45	0.321
Crawford	-4.39	4.45	0.847
Ehlers	0.73	-0.06	10.8
Gibbons	0.73	0.73	30.6
Stetson	-0.46	1.22	15.1
Knode	-1.89	2.68	3.97
Brott	-1.37	1.34	3.64
McDowell	-2.16	4.36	3.08
Taggart	-1.89	4.45	3.28
Franey	-0.98	4.76	4.19
Bunch	1.01	4.27	5.45
Dyer	-2.44	0.55	1.77

Table 3.0-2: MILDOS Results for Grid Point Receptors Based on 2000 Hour/Year Occupancy

Grid Point	X(KM)	Y(KM)	Dose (mrem/yr)	Grid Point	X(KM)	Y(KM)	Dose (mrem/yr)	Grid Point	X(KM)	Y(KM)	Dose (mrem/yr)
G10-1	-0.01	-0.01	0.6	G250-1	-0.5	-0.5	5.4	G1000a-24	-3	-4	0.4
G10-2	-0.01	0	0.6	G250-2	-0.5	-0.25	3.6	G1000a-25	-3	-3	0.5
G10-3	-0.01	0.01	0.6	G250-3	-0.5	0	1.9	G1000a-26	-3	-2	0.5
G10-4	0	-0.01	0.6	G250-4	-0.5	0.25	1.9	G1000a-27	-3	-1	0.4
G10-5	0	0.01	0.6	G250-5	-0.5	0.5	2.4	G1000a-28	-3	0	0.3
G10-6	0.01	-0.01	0.6	G250-6	-0.25	-0.5	7.1	G1000a-29	-3	1	0.3
G10-7	0.01	0	0.6	G250-7	-0.25	-0.25	12.4	G1000a-30	-3	2	0.4
G10-8	0.01	0.01	0.6	G250-8	-0.25	0	4.2	G1000a-31	-3	3	0.4
G50a-1	-0.2	-0.2	15.2	G250-9	-0.25	0.25	4.3	G1000a-32	-3	4	0.5
G50a-2	-0.2	-0.15	13.2	G250-10	-0.25	0.5	7.4	G1000a-33	-3	5	0.5
G50a-3	-0.2	-0.1	9.1	G250-11	0	-0.5	3.7	G1000a-34	-2	-5	0.4
G50a-4	-0.2	-0.05	6.8	G250-12	0	-0.25	10.6	G1000a-35	-2	-4	0.5
G50a-5	-0.2	0	5.2	G250-13	0	0	0.6	G1000a-36	-2	-3	0.7
G50a-6	-0.2	0.05	4.1	G250-14	0	0.25	24.9	G1000a-37	-2	-2	0.9
G50a-7	-0.2	0.1	3.6	G250-15	0	0.5	16.7	G1000a-38	-2	-1	0.7
G50a-8	-0.2	0.15	4.6	G250-16	0.25	-0.5	4.5	G1000a-39	-2	0	0.4
G50a-9	-0.2	0.2	5.1	G250-17	0.25	-0.25	9.0	G1000a-40	-2	1	0.5
G50a-10	-0.15	-0.2	16.5	G250-18	0.25	0	5.7	G1000b-1	-2	2	0.6
G50a-11	-0.15	-0.15	18.6	G250-19	0.25	0.25	19.0	G1000b-2	-2	3	0.8
G50a-12	-0.15	-0.1	14.2	G250-20	0.25	0.5	12.6	G1000b-3	-2	4	0.8
G50a-13	-0.15	-0.05	8.3	G250-21	0.5	-0.5	4.2	G1000b-4	-2	5	0.6
G50a-14	-0.15	0	6.5	G250-22	0.5	-0.25	3.4	G1000b-5	-1	-5	0.4
G50a-15	-0.15	0.05	4.1	G250-23	0.5	0	3.4	G1000b-6	-1	-4	0.6
G50a-16	-0.15	0.1	5.0	G250-24	0.5	0.25	7.7	G1000b-7	-1	-3	0.8
G50a-17	-0.15	0.15	6.0	G250-25	0.5	0.5	10.5	G1000b-8	-1	-2	1.2
G50a-18	-0.15	0.2	8.4	G500-1	-1.5	-1.5	1.3	G1000b-9	-1	2	1.6
G50a-19	-0.1	-0.2	16.9	G500-2	-1.5	-1	1.2	G1000b-10	-1	3	1.4
G50a-20	-0.1	-0.15	19.3	G500-3	-1.5	-0.5	0.8	G1000b-11	-1	4	1.1
G50a-21	-0.1	-0.1	20.1	G500-4	-1.5	0	0.6	G1000b-12	-1	5	0.9
G50a-22	-0.1	-0.05	10.6	G500-5	-1.5	0.5	0.7	G1000b-13	0	-5	0.4
G50a-23	-0.1	0	6.9	G500-6	-1.5	1	0.8	G1000b-14	0	-4	0.6
G50a-24	-0.1	0.05	4.0	G500-7	-1.5	1.5	0.8	G1000b-15	0	-3	0.8
G50a-25	-0.1	0.1	6.5	G500-8	-1	-1.5	1.6	G1000b-16	0	-2	1.3
G50a-26	-0.1	0.15	9.9	G500-9	-1	-1	2.2	G1000b-17	0	2	3.6
G50a-27	-0.1	0.2	12.4	G500-10	-1	-0.5	1.6	G1000b-18	0	3	2.1
G50a-28	-0.05	-0.2	15.6	G500-11	-1	0	0.9	G1000b-19	0	4	1.5
G50a-29	-0.05	-0.15	17.9	G500-12	-1	0.5	1.1	G1000b-20	0	5	1.1
G50a-30	-0.05	-0.1	18.2	G500-13	-1	1	1.2	G1000b-21	1	-5	0.4
G50a-31	-0.05	-0.05	14.8	G500-14	-1	1.5	1.7	G1000b-22	1	-4	0.4

Grid Point	X(KM)	Y(KM)	Dose (mrem/yr)	Grid Point	X(KM)	Y(KM)	Dose (mrem/yr)	Grid Point	X(KM)	Y(KM)	Dose (mrem/yr)
G50a-32	-0.05	0	2.7	G500-15	-0.5	-1.5	1.9	G1000b-23	1	-3	0.5
G50a-33	-0.05	0.05	5.3	G500-16	-0.5	-1	2.9	G1000b-24	1	-2	0.8
G50a-34	-0.05	0.1	8.6	G500-17	-0.5	1	3.6	G1000b-25	1	2	2.7
G50a-35	-0.05	0.15	14.0	G500-18	-0.5	1.5	3.0	G1000b-26	1	3	1.8
G50a-36	-0.05	0.2	18.1	G500-19	0	-1.5	1.9	G1000b-27	1	4	1.3
G50a-37	0	-0.2	12.1	G500-20	0	-1	2.9	G1000b-28	1	5	1.1
G50a-38	0	-0.15	13.6	G500-21	0	1	8.5	G1000b-29	2	-5	0.3
G50a-39	0	-0.1	14.2	G500-22	0	1.5	5.2	G1000b-30	2	-4	0.3
G50a-40	0	-0.05	8.1	G500-23	0.5	-1.5	1.4	G1000b-31	2	-3	0.4
G50b-1	0	0.05	4.7	G500-24	0.5	-1	2.2	G1000b-32	2	-2	0.6
G50b-2	0	0.1	13.1	G500-25	0.5	1	6.5	G1000b-33	2	-1	0.6
G50b-3	0	0.15	21.9	G500-26	0.5	1.5	4.4	G1000b-34	2	0	0.8
G50b-4	0	0.2	25.3	G500-27	1	-1.5	1.2	G1000b-35	2	1	1.5
G50b-5	0.05	-0.2	12.0	G500-28	1	-1	2.2	G1000b-36	2	2	1.9
G50b-6	0.05	-0.15	12.9	G500-29	1	-0.5	1.8	G1000b-37	2	3	1.5
G50b-7	0.05	-0.1	11.7	G500-30	1	0	1.9	G1000b-38	2	4	1.1
G50b-8	0.05	-0.05	6.6	G500-31	1	0.5	3.7	G1000b-39	2	5	0.9
G50b-9	0.05	0	3.3	G500-32	1	1	4.7	G1000b-40	3	-5	0.2
G50b-10	0.05	0.05	9.1	G500-33	1	1.5	3.6	G1000c-1	3	-4	0.3
G50b-11	0.05	0.1	13.0	G500-34	1.5	-1.5	0.9	G1000c-2	3	-3	0.4
G50b-12	0.05	0.15	18.4	G500-35	1.5	-1	1.0	G1000c-3	3	-2	0.4
G50b-13	0.05	0.2	21.8	G500-36	1.5	-0.5	1.0	G1000c-4	3	-1	0.3
G50b-14	0.1	-0.2	11.5	G500-37	1.5	0	1.2	G1000c-5	3	0	0.5
G50b-15	0.1	-0.15	13.2	G500-38	1.5	0.5	1.9	G1000c-6	3	1	0.7
G50b-16	0.1	-0.1	12.6	G500-39	1.5	1	2.6	G1000c-7	3	2	1.1
G50b-17	0.1	-0.05	6.8	G500-40	1.5	1.5	2.8	G1000c-8	3	3	1.1
G50b-18	0.1	0	6.6	G1000a-1	-5	-5	0.3	G1000c-9	3	4	1.0
G50b-19	0.1	0.05	11.7	G1000a-2	-5	-4	0.3	G1000c-10	3	5	0.8
G50b-20	0.1	0.1	20.2	G1000a-3	-5	-3	0.3	G1000c-11	4	-5	0.2
G50b-21	0.1	0.15	21.2	G1000a-4	-5	-2	0.2	G1000c-12	4	-4	0.3
G50b-22	0.1	0.2	20.2	G1000a-5	-5	-1	0.2	G1000c-13	4	-3	0.3
G50b-23	0.15	-0.2	11.6	G1000a-6	-5	0	0.2	G1000c-14	4	-2	0.2
G50b-24	0.15	-0.15	13.2	G1000a-7	-5	1	0.2	G1000c-15	4	-1	0.3
G50b-25	0.15	-0.1	10.2	G1000a-8	-5	2	0.2	G1000c-16	4	0	0.3
G50b-26	0.15	-0.05	6.8	G1000a-9	-5	3	0.2	G1000c-17	4	1	0.5
G50b-27	0.15	0	7.0	G1000a-10	-5	4	0.2	G1000c-18	4	2	0.6
G50b-28	0.15	0.05	12.5	G1000a-11	-5	5	0.2	G1000c-19	4	3	0.8
G50b-29	0.15	0.1	18.6	G1000a-12	-4	-5	0.3	G1000c-20	4	4	0.8
G50b-30	0.15	0.15	23.7	G1000a-13	-4	-4	0.4	G1000c-21	4	5	0.7
G50b-31	0.15	0.2	21.8	G1000a-14	-4	-3	0.4	G1000c-22	5	-5	0.2

Grid Point	X(KM)	Y(KM)	Dose (mrem/yr)	Grid Point	X(KM)	Y(KM)	Dose (mrem/yr)	Grid Point	X(KM)	Y(KM)	Dose (mrem/yr)
G50b-32	0.2	-0.2	11.1	G1000a-15	-4	-2	0.3	G1000c-23	5	-4	0.2
G50b-33	0.2	-0.15	10.0	G1000a-16	-4	-1	0.3	G1000c-24	5	-3	0.2
G50b-34	0.2	-0.1	7.4	G1000a-17	-4	0	0.2	G1000c-25	5	-2	0.2
G50b-35	0.2	-0.05	6.6	G1000a-18	-4	1	0.2	G1000c-26	5	-1	0.2
G50b-36	0.2	0	6.5	G1000a-19	-4	2	0.2	G1000c-27	5	0	0.2
G50b-37	0.2	0.05	11.1	G1000a-20	-4	3	0.2	G1000c-28	5	1	0.3
G50b-38	0.2	0.1	15.0	G1000a-21	-4	4	0.2	G1000c-29	5	2	0.4
G50b-39	0.2	0.15	19.4	G1000a-22	-4	5	0.3	G1000c-30	5	3	0.5
G50b-40	0.2	0.2	21.8	G1000a-23	-3	-5	0.4	G1000c-31	5	4	0.6
								G1000c-32	5	5	0.6

Floor Exhaust Vent Fan

Tank Vent Number

TANK VENT LOCATIONS

1 - West IX Blower
2 - East IX Blower
3 - Eluant Blower
4 - Waste Blower
5 - Bicarb Mix Tank Blower
6 - Column Drain Blower
7 - Precip Tank Blower
8 - Precip A Tank Blower