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CROW BUTTE OPERATION

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

Request for Additional Clarification for Response to License Condition 11.10
Crow Butte Resources, Inc., Crawford, Nebraska
Source Materials License SUA-1534
TAC No: L00760

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 (LC) 11.10 of the renewed license required CBR to submit information on its contamination survey program for the NRC staff's written verification. Specifically LC 11.10 required the licensee to submit the following information:

> A survey program for beta/gamma contamination for personnel exiting from restricted areas, and beta/gamma contamination in unrestricted and restricted areas that will meet the requirements of 10 CFR Part 20, Subpart F and submit the program to NRC for review and written verification.
>
> A review and written verification the surface contamination detection capability (Minimum Detection Concentration (MDC)) for radiation survey instruments, including scan MDC for portable instruments, used for contamination surveys to release equipment and materials for unrestricted use and for personnel contamination surveys. The detection capability in the scanning mode for the alpha and beta radiation expected shall be provided in terms of dpm per 100 cm^2.

NMSS20

By letter dated December 19, 2014, CBR submitted to the NRC staff a response to LC 11.10. By letter dated July 5, 2016, the NRC staff requested additional clarification for the review of License Condition (LC) 11.10 of the renewed license. The NRC staff comments below are organized according to the sections in the licensee's submittal.

Comments on Personnel Surveys:

Issue 1: Calculation of Minimum Detectable Concentration (MDC)

Crow Butte Stated:
"The Minimum Detectable Concentration (MDC) for scalar alpha and beta/gamma measurements using hand held probes will be determined based on the method in NUREG 1507, shown equation (1)".

Where Equation (1) is presented as:

$$MDC\left(\frac{DPM}{100cm^2}\right) = \frac{3+3.29\sqrt{R_b\, t_g(1+\frac{t_g}{t_b})}}{\varepsilon_i t_g(\frac{SA}{100cm^2})} \qquad (1)$$

where: R_b = the background count rate
t_g = the sample count time
t_b = the background count time
ε_i = the instrument efficiency
SA = probe surface area (cm^2)

Discussion
The NRC staff observes that the licensee's formula for the static MDC (Equation (1) above) is consistent with the form of the formula presented in Table 3.1 of NUREG-1507 (NRC, 1998) from the Strom & Stansbury reference, corrected for probe area. However, the efficiency term, ε_i, in the denominator of the licensee's Equation (1) above should be the counting, or total, efficiency, not the instrument efficiency. This was previously communicated to the licensee in NRC, 2014b.

NUREG-1507 (NRC, 1998) endorses the approach in the International Organization for Standardization standard ISO 7503-1, Evaluation of Surface Contamination – Part 1: Beta Emitters and Alpha Emitters (first edition), for calculating the counting, or total, efficiency. The counting efficiency is comprised of the instrument efficiency and the source efficiency. See the NRC staff discussion in Enclosure 1 of NRC, 2015b, under the heading *Counting Efficiencies of Ludlum Model 3030 and 43-93.*

NRC Staff Comment 1
Please provide a methodology for calculating the static MDC that includes appropriate factors affecting the counting efficiency consistent with NUREG-1507 (NRC, 1998), or justification for an alternate methodology.

Crow Butte Response
The Minimum Detectable Concentration (MDC) for scalar alpha and beta/gamma measurements using hand held probes will be revised to follow the method in NUREG 1507, as shown in the following equation:

$$MDC\left(\frac{DPM}{100cm^2}\right) = \frac{3 + 3.29\sqrt{R_b\, t_g(1 + \frac{t_g}{t_b})}}{\varepsilon_t t_g(\frac{SA}{100cm^2})}$$

where: R_b = the background count rate
t_g = the sample count time
t_b = the background count time
ε_t = total efficiency (instrument efficiency * source efficiency)
SA = probe surface area (cm^2)

Additional discussion on determination of ε_t is included in the response to Issue 2.

Issue 2: Determining Alpha and Beta Instrument Efficiencies

Crow Butte Stated:
"The typical beta/gamma efficiency for a 43-93 probe is 18 – 23 percent, therefore a value of 18 percent will be used in the nominal MDC calculations. For alpha efficiency, typical alpha detector efficiencies measured at site, which generally range from 13 – 22 percent, depending on the detector. A value of 13 percent has been assumed for the nominal calculations. The actual detector efficiency is determined for each probe on a routine basis, as per site procedures, using a natural uranium check source to ensure the efficiency is accurate and based on the applicable energy range for the contamination it is being used to measure".
In addition, Crow Butte stated the following regarding probe efficiencies for beta/gamma contamination:

"Note, these are nominal calculations, actual probe efficiencies may be used to determine limits for each detector and/or location".

Discussion
It is unclear to the NRC staff exactly how counting efficiencies will be determined for alpha and beta detectors.

As discussed in Issue 1 above, the MDC calculation should take the source efficiency into account in deriving the MDC. Moreover, consistent with NUREG-1507 (NRC, 1998) (see, for example, the discussion on page 5-14) and NUREG-1575, Supplement 1 (NRC, 2009), a weighted total efficiency should be calculated for the expected mixture of radionuclides to be evaluated. As a minimum, this should include aged yellowcake and pregnant lixiviant. See also NRC staff RAI No.3 in NRC, 2015a.

In addition, the NRC staff is uncertain of the pedigree of the source(s) being used to evaluate the efficiency of the detectors. While a radioactive standard that is traceable to National Institute of Standards and Technology (NIST), for example, would be suitable for calibration, a check source would not necessarily be appropriate (ANSI, 2013). See the discussion in Enclosure 1 of NRC, 2015b, under the heading *Calibration sources.*

NRC Staff comment 2
Please provide the methodology for calculating radionuclide-weighted alpha and beta counting efficiencies for the major radionuclide mixtures likely to be encountered at the Crow Butte Project. This should include, at a minimum, radionuclide mixtures for pregnant lixiviant and aged yellowcake.

As part of this description, please provide information on the radioactive source(s) used for determining the instrument efficiency of the alpha and beta detectors. This discussion should include information related to the physical size(s) of the source(s) in comparison to the active area of the probe(s) being calibrated and traceability (e.g., NIST) for the NRC staff to make a determination of consistency with applicable standards (e.g., ANSI, 2013).

Crow Butte Response
CBO will utilize the method described in (Strata Energy Inc., 2015) for calculating radionuclide-weighted alpha and beta counting efficiencies for the major radionuclide mixtures, namely aged yellowcake and pregnant lixiviant.

First, in regards to aged yellowcake alpha emissions, CBO uses a certified NIST traceable natural uranium sources for determining alpha efficiencies of the hand held contamination monitoring equipment. The records are available on site for inspection. Because the source is identical in energy emissions to the alpha emitters from aged yellowcake (i.e. U238, U235 and U234 in natural abundance), the alpha instrument efficiencies calculated with this source are radionuclide-weighted efficiencies for aged yellowcake alpha emissions. No additional calculations are required for this radiation type and product. These sources have a 150 cm^2 surface area and the ratio between source and probe surface areas are included in the equipment efficiency calculation. A source efficiency of 0.25, as recommended by ISO 7503-1, will be used in combination with the instrument efficiency to calculate total efficiency. Table 2 below, shows an example of calculation of instrument efficiency using this source; the instrument efficiency was 35.9%. Multiplying that by the source efficiency of 25% results in a total efficiency of 9%.

In regards to beta emissions from aged yellowcake, while use of the same natural uranium source would be ideal, because the uranium is in radioactive equilibrium with its short lived beta-emitting decay products, this source does not currently have an NIST traceable calibration certificate for beta emission. Therefore Sr/Y-90 and C14 sources, which are NIST traceable with records available on site for inspection, will be used to determine instrument efficiency for beta emissions and the methodology from (Strata Energy Inc., 2015) used to determine a total radionuclide weighted efficiency.

Tables 1 and 2 show an example of the calculation of the instrument efficiency for the Ludlum Model 43-93. The instrument efficiency, ε_i, was calculated according to the method outlined in ISO 7503-1 (ISO, 1988), namely that ε_i = (measured counts (cpm) – background counts (cpm)) / source surface emission rate (dpm). Note if the source area is greater than the probe area, source emissions (dpm) must be modified by ratio of (probe area/source area) to ensure the correct emissions are used. The instrument efficiency for the Model 43-93 is 35.9% for alpha (as per discussion above) and 52.2% for beta. It is important to note for clarity that the term 'source efficiency' as used by ISO 7503-1 refers to an actual alpha or beta contamination source (i.e. the object being measured for release), not to a reference source.

Table 1: Calibration Source Data

Source Isotope	Source ID	Source Activity (dpm)	Source Surface Emission (dpm)
U^{nat}	K1-076	23000	11390
Sr/Y-90	M2-098	189800	113800

Table 2: Instrument Efficiency Calculation

Source #	K1-076	M2-098
Total Activity (dpm)	11390	113800
Alpha 5 min bkg	31	

Beta 5 min bkg		1093
Source Size	150 cm^2	
Probe Size	100 cm^2	100 cm^2
	Alpha	Beta
Count 1	2657	59567
Count 2	2799	59632
Count 3	2772	59479
Count 4	2791	59319
Count 5	2747	60018
Count 6	2638	59449
Count 7	2781	59937
Count 8	2720	59637
Count 9	2671	59535
Count 10	2764	59924
Average cpm	2734	59649.7
Source Surface Emission (dpm)	11390	113800
Instrument Efficiency**	**35.90%**	**52.20%**
	**(radionuclide weighted)	

The radionuclide mixture weighted counting efficiency for beta for aged yellowcake was calculated using the methodology outlined in the draft (Strata Energy Inc., 2015) and is shown in Table 3. Because the lower energy beta emitters in aged yellowcake (i.e. Th-231 and Th-234) are not present in the Sr/Y 90 source, the instrument efficiency for these radionuclides will be assumed to be zero. The source for the uranium and activity fraction are NRC, 2015. The source for the energy and branching ratio are from Table 2-2 of DOE, 2009 (low yield radiations are not included). The total weighted beta efficiency for the Model 43-93 for aged yellowcake is 12.5%. As stated earlier the total weighted alpha instrument efficiency for aged yellowcake is 9.0%.

Table 3: Mixture Weighted Beta Efficiency for Aged Yellowcake for Model 43-93

Isotope	Energy (keV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency

Th-234	103	0.489	0.21	0	0.25	0.0000
Th-234	193	0.489	0.79	0	0.25	0.0000
Pa-234m	2290	0.489	0.98	0.522	0.50	0.1251
Th-231	206	0.022	0.13	0	0.25	0.0000
Th-231	287	0.022	0.12	0	0.25	0.0000
Th-231	288	0.022	0.37	0	0.25	0.0000
Th-231	305	0.022	0.35	0	0.25	0.0000

Beta Counting Efficiency = 0.1251

The pregnant lixiviant is the process fluid which is returning from the wellfield to the plant, and will contain higher concentrations of radionuclides than the "barren lixiviant", or the process fluids which return to the wellfield after passing over the resin beds. In considering the mixtures, CBO has not taken into account radon gas (Rn-222) nor the short lived decay products of radon (radon daughters). Although the radon daughters are alpha and beta emitters, they were excluded from the calculations as the calculations are considering surface contamination levels, not airborne contamination levels.

Strata (Strata Energy Inc., 2015; hereon referred to as "Strata") provided a very detailed explanation as to the assumptions used to determine the radionuclide composition for pregnant lixiviant. Currently, no assays of the Crow Butte lixiviant are available, therefore the same assumptions as those in the approved Strata application will be used. Crow Butte Operation uses an alkaline based mining method similar to Stata and the referenced data sources. As such, the same assumptions will be adopted for CBO. Specifically, Strata identified (DOE, 2009) as the source for aged yellowcake composition and two sources of data were identified regarding the radionuclide composition in lixiviant (Brown, 1982 and LCI, 2015). The LCI, 2015 document contained a radionuclide composition analysis on pregnant lixiviant from a Uranium Recovery facility in Wyoming, using alkaline based mining techniques similar to that proposed by CBO. The LCI, 2015 document showed that the concentrations of the long-lived decay products of natural uranium in the pregnant lixiviant are negligible. Two radionuclides had elevated concentrations, namely Ra-226 and Th-234, with concentrations of 2,700 and 2,290 pCi/L respectively. Converting to Bq/L yields Ra-226 and Th-234 concentrations of 99.9 and 84.7 Bq/L respectively. The paper (Brown, 1982) lists concentrations for Th-230 and Ra-226. The concentration ranges for Th-230 are 56 - 93 Bq/L, and for Ra-226 are 10 - 150 Bq/L. To be conservative, the upper end of the higher concentrations, specifically 150 Bq/L for Ra-226 and 93 Bq/L for Th230, will be used for this analysis.

As there was no data regarding the concentrations of Th-231 and Pa-234m for the pregnant lixiviant, in alignment with the Strata application, CBO made the following estimations: for Th-231 and Pa-234m, it is assumed that Th-231 was in secular equilibrium with U-235 and Pa-234m was in secular equilibrium with Th-234. This estimation is valid as the half-lives of the parent radionuclides are much longer than the half-lives of the daughter radionuclides.

The activity fractions for pregnant lixiviant were calculated using the data and estimations listed above. The specific activity of 6.77E-7 Ci/g for natural Uranium was found in footnote (3) to Appendix B of 10 CFR 20. An average concentration of uranium in pregnant lixiviant is 25-30 ppm, and a conservative estimate of the concentration of uranium in the pregnant lixiviant which will be used is 40 ppm. Converting to Bq/L yields:

Concentration of U in pregnant lixiviant = 40 ppm = 40 mg/L = 0.04 g/L = 1E3 Bq/L

Therefore, the primary radionuclides of concern for contamination from pregnant lixiviant in regards to alpha and beta radiation are shown in Tables 4 and 5. Natural uranium, in Table 4, has been broken down by radionuclide according to natural abundance ratios.

Table 4: Primary Alpha Emitting Radionuclides in Lixiviant

	Bq/L	Fraction
U (total)	1,000	0.805
U-238	486	0.391
U-235	22	0.018
U-234	492	0.396
Th-230	93	0.075
Ra-226	150	0.121

Table 5: Primary Beta Emitting Radionuclides in Lixiviant

	Bq/L	Fraction
Th-234	84.7	0.443
Th-231	22	0.115
Pa-234m	84.7	0.443

Again following the process described in (NRC, 2015) the radionuclide mixture weighted counting efficiency was determined for lixiviant for both alpha and beta, shown in Tables 6. The instrument efficiencies were again taken from Table 2 and the default source efficiencies, as recommended by ISO 7503-1 were used. The source for the activity fractions are Strata Energy Inc., 2015, LCI, 2015, and Brown, 1982. The sources for the energy and branching ratio are from Table 2-2 of DOE, 2009 and the Health Physics and Radiological Health Handbook (1992) (low yield radiations are not included).

Because CBO does not have a traceable beta calibration source which emits beta particles at energies similar to the lower energy betas emitters (i.e. Th-231 and Th-234), the instrument efficiency for those radionuclides is listed as zero. The Y90 emission at 2.245 MeV is comparable to the 2.29 MeV emission of Pa-234m. To better account for the low energy emissions, a C-14 source will be purchased and the beta mixture efficiency recalculated at that time.

Table 6: Mixture Weighted Efficiencies for Pregnant Lixiviant.

Isotope	Energy (MeV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
U-238	4.15	0.391	0.21	0.359	0.25	0.0074
U-238	4.20	0.391	0.79	0.359	0.25	0.0277
U-234	4.72	0.396	0.28	0.359	0.25	0.0100
U-234	4.77	0.396	0.72	0.359	0.25	0.0256
U-235	4.21	0.018	0.06	0.359	0.25	0.0001
U-235	4.37	0.018	0.17	0.359	0.25	0.0003
U-235	4.40	0.018	0.55	0.359	0.25	0.0009
U-235	4.60	0.018	0.05	0.359	0.25	0.0001
Th-230	4.62	0.075	0.24	0.359	0.25	0.0016
Th-230	4.68	0.075	0.76	0.359	0.25	0.0051
Ra-226	4.60	0.121	0.06	0.359	0.25	0.0007
Ra-226	4.78	0.121	0.95	0.359	0.25	0.0103

Alpha Counting Efficiency = 0.0897

Isotope	Energy (keV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
Th-234	103	0.443	0.21	0	0.25	0.0000
Th-234	193	0.443	0.79	0	0.25	0.0000
Pa-234m	2290	0.443	0.98	0.522	0.50	0.1133
Th-231	206	0.115	0.13	0	0.25	0.0000
Th-231	287	0.115	0.12	0	0.25	0.0000
Th-231	288	0.115	0.37	0	0.25	0.0000
Th-231	305	0.115	0.35	0	0.25	0.0000

Beta Counting Efficiency = 0.1133

In regards to the alpha efficiency for pregnant lixiviant, the same final efficiency can be achieved by simply multiplying the instrument efficiency (35.9%) by the source efficiency (25%). Therefore, for alpha efficiency determination, the simpler methodology of multiplying the instrument and source efficiency will be used for both yellowcake and lixiviant total efficiency calculations.

In summary, the two mixture weighted efficiencies for alpha and beta are shown in Table 7, note this is based on the instrument efficiency calculation shown in Table 2.

Table 7: Summary of Instrument Weighted Efficiencies

Mixture	Radiation Type	Total Efficiency (NRC, 2015 method)
Aged Yellowcake	Alpha	9.0%
	Beta	12.5%
Pregnant Lixiviant	Alpha	9.0%
	Beta	11.3%

While in some cases it may be possible to establish the actual nature of the contaminant on a surface, e.g. yellowcake drums; this would be the exception. In most cases, it will not be possible to conclusively say that a surface had the potential to be contaminated by only one form of material or another. In addition, trying to manage material specific efficiencies actually increases error potential due to the increased complexity of the process. Therefore, practically, the only reasonable option is to use the more restrictive efficiency unless it is possible to conclusively say what the contaminant is. Crow Butte will calculate the efficiency for both mixtures for its equipment, however in most cases it will be the more restrictive efficiency that is used for the calculations.

Comments on Material & Equipment Surveys

Issue 3: MDC value for beta contamination on material and equipment

Discussion

As discussed above in Issues 1 and 2, the source efficiency and actual instrument efficiency will determine the MDC for beta emitting radionuclides.

NRC staff comment 3

After calculating radionuclide-weighted beta counting efficiencies for the major radionuclide mixture likely to be encountered at the Crow Butte Project, please demonstrate that the stated MDC values for beta contamination on material and equipment can be met.

Crow Butte Response

As stated previously, the removable release limit in Regulatory Guide 8.30 is 1000 dpm/100cm^2, the average total activity limit is 5000 dpm/100cm^2 and the total maximum activity limit is 15,000 dpm/100 cm^2. In addition, the site procedural requirement to collect alpha smears if contamination levels exceed 750 dpm/100cm^2 remains in place.

For static measurements, the following formula will be applied:

$$MDC\left(\frac{DPM}{100cm^2}\right) = \frac{3 + 3.29\sqrt{R_b\, t_g(1+\frac{t_g}{t_b})}}{\varepsilon_t t_g(\frac{SA}{100cm^2})}$$

where: R_b = the background count rate
t_g = the sample count time
t_b = the background count time
ε_t = the total efficiency
SA = probe surface area (cm^2)

There are numerous combinations of background and count times that can be used, however as an example, for beta emitting radionuclides, using a probe surface area of 100 cm^2, an efficiency of 11.3%, and a 1 minute sample count on materials and equipment, to meet the criteria of 750 dpm/100cm^2 the background rate is required to be 308 counts in 1 minute or 2575 counts in 5 minutes. If this background count rate is exceeded then smears may be required for loose contamination in order to release the equipment, as per existing site procedure, or the equipment will need to be moved to a lower background area within the controlled area for surveying.

Issue 4: MDC value for alpha contamination on material and equipment

Crow Butte Stated:
"For materials and equipment, Regulatory Guide 8.30 indicates the removable release limit is 1000 dpm/100cm^2, the average total activity limit is 5000 dpm/100 cm^2 and the total maximum activity limit is 15,000 dpm/100 cm^2. Using the previous mentioned assumptions, if the background levels for beta/gamma reach 3,450 counts in 5 minutes or 500 counts in 1 minute, this will result in MDCs of 745 dpm/100 cm^2 and 741 dpm/100 cm^2, respectively. If this background count rate is exceeded then smears will be required in order to release the equipment, as per existing procedure, or the equipment will need to be moved to a lower background area for surveying. If contamination levels exceed 750 dpm/100 cm^2, an alpha smear will be required. Prior to leaving the restricted zone, the equipment must meet the alpha release limits outlined in Regulatory Guide 8.30".

Discussion
It is not clear to the NRC staff what MDC value the licensee is applying to alpha contamination for the release of material and equipment for unrestricted release. Regulatory Guide (RG) 8.30 (NRC, 2002) recommends that the value of the lower limit of detection be 500 dpm/100 cm^2.

NRC staff comment 4
Please provide the MDC value to be applied to alpha contamination for the release of material and equipment for unrestricted release.

In addition, after calculating radionuclide-weighted alpha counting efficiencies for the major radionuclide mixtures likely to be encountered at the Crow Butte Project, please demonstrate that the stated MDC value for alpha contamination on material and equipment can be met.

Crow Butte Response
The MDC of 500 dpm/100cm^2, as referenced in Regulatory Guide 8.30, will be used for the alpha MDC value. The alpha static MDC will be calculated using the following formula:

$$MDC\left(\frac{DPM}{100cm^2}\right)=\frac{3+3.29\sqrt{R_b\,t_g(1+\frac{t_g}{t_b})}}{\varepsilon_t t_g(\frac{SA}{100cm^2})}$$

where: R_b = the background count rate
t_g = the sample count time
t_b = the background count time
ε_t = the total efficiency
SA = probe surface area (cm^2)

Assuming a background count rate of 15 counts in 1 minutes, a 100 cm^2 probe area and a 30 second sample count time, the MDC for a mixture efficiency of 9.0% would be 312 dpm/100 cm^2. These values are conservative, because alpha background rates are typically less than 15 cpm, meaning actual MDC's will typically be less than this value.

Issue 5: Value for scan time, t_s, used in scan MDC formula

The licensee used Equation 6-2 from NUREG-1507 (NRC, 1998) to calculate the scan MDC for beta-gamma contamination. This is rewritten as Equation (2) in the licensee's December 19, 2014 submittal (Cameco, 2014) as follows:

$$Scan\ MDC\left(\frac{DPM}{100cm^2}\right)=\frac{d'\left(\frac{60}{t_s}\right)\sqrt{b\left(\frac{t_s}{60}\right)}}{\sqrt{p}\epsilon_i\epsilon_s\frac{Probe\ Area}{100\ cm^2}} \qquad (2)$$

Where: t_s = Scan time (sec)
d' = level of performance (Table 6.1 from NUREG 1507) (false negative portion = 0.6, true positive = 0.95)
b_i = average number of bkg counts in interval (cpm)
p = surveyor efficiency; assumed 0.5
ϵ_i = instrument efficiency (22%)
ϵ_s = surface efficiency (0.5) from section 5 of NUREG 1507

In addition, the licensee stated:

"The planned scan rate is 1 cm/sec. With a 15 cm probe length, this scan rate equates to a scan time of 15 seconds".

Discussion

The NRC staff observes that the standard Ludlum Model 43-93 probe has a rectangular shape with a maximum active length of 14.48 cm, with the shorter active probe dimension being 6.93 cm (Ludlum, 2016). Using 14.48 cm instead of 15 cm would result in a slightly reduced scanning time if the maximum dimension was used for scanning consistently. Using the shorter active probe dimension would significantly decrease the scan time with a corresponding increase of the scan MDC. Although the licensee committed to recalculating the scan MDC if the scanning rate is changed, it is not clear to the NRC staff how the licensee will ensure that the maximum dimension is used consistently for scanning materials and equipment. This could be accomplished, for example, by procedures and training.

<u>NRC staff comment 5</u>
Please confirm that the actual active dimensions of the probe will be used for determining the scan MDC. In addition, please provide information on how the licensee will ensure scans will be performed in a manner consistent with the calculated scan time used to calculate the scan MDC.

<u>Crow Butte Response</u>
See response to Issue 6.

Issue 6: Description of level of performance, d', used in scan MDC formula

Refer to licensee's Equation (2) in Issue 5 above.

<u>Discussion</u>
Table 6.1 of NUREG-1507 (NRC, 1998) lists values for d' based on the accepted false positive proportion and true positive proportion. There appears to be a typographical error in the licensee's description of the value for d' that it chose, "false negative portion = 0.6".

<u>NRC staff comment 6</u>
Please address typographical error in the description of d'.

<u>Crow Butte Response</u>
Crow Butte Operation does not intend to use scanning as a methodology for performing contamination monitoring. This equation was included in the submission as a contingency, should we decide to do this in the future, and because it was requested by the NRC. Because we are not currently planning to use this methodology, we are withdrawing any reference to the use of scanning from the submission. Only static monitoring will be used by the facility.

Issue 7: Average number of background counts in interval, b_i.

Refer to licensee's Equation (2) in Issue 5 above.

Discussion
The licensee defines "b_i" in Equation (2). This definition is consistent with NUREG-1507 (NRC, 1998). However, the licensee use "b" (no subscript "i") in Equation (2), which is not defined.

NRC staff comment 7

Please provide a definition for "b" (no subscript "i") in Equation (2).

Crow Butte Response
As per Issue 6, this process will not be used and is being withdrawn from the submission.

Issue 8: Efficiency values used in scan MDC formula

Refer to licensee's Equation (2) in Issue 5 above.

Discussion
As discussed above in Issues 1 and 2, the source efficiency and actual instrument efficiency calculated on a radionuclide-weighted basis will determine the MDC for beta emitting radionuclides.

In addition, using the licensee's assumed values, the NRC staff calculated a scan MDC of greater than 100 dpm/100 cm^2.

NRC staff comment 8
After calculating radionuclide-weighted beta counting efficiencies for the major radionuclide mixtures likely to be encountered at the Crow Butte Project, please demonstrate that the stated scan MDC value for beta contamination on material and equipment can be met.

Crow Butte Response
As per Issue 6, this process will not be used and is being withdrawn from the submission.

Issue 9: Use of the scan MDC

Refer to the description of Issue 5 above.

Discussion
The scan MDC Equation 6-2 from NUREG-1507 is based on the premise that there are two stages of scanning (refer to p. 6-16 of NRC, 1998, and p. 6-39 of NRC, 2000): continuous monitoring and stationary sampling. The licensee has chosen a relatively high rate of false positive for the first stage in scanning. After detecting an increased number of counts during the first stage of scanning, the individual performing the scan should perform a stationary scan and compare the results to the background counting rate.

NRC staff comment 9
Please describe how the scan MDC will be utilized at the Crow Butte Facility. Specifically, please address what actions will be required when individuals performing a scan detect an increased number of counts during the first stage of scanning and how these required actions will be maintained consistently among various individuals performing the scans, such as by written procedures and training.

Crow Butte Response
As per Issue 6, this process will not be used and is being withdrawn from the submission.

Issue 10: No scan MDC calculation

Discussion:
In its September 4, 2014, e-mail to the licensee (NRC, 2014b), the NRC staff notified the licensee that the scan MDC formula presented in Equation 6-2 from NUREG-1507 (NRC, 1998) (see Issue 5 above) is not appropriate for alpha contamination. The licensee did not propose a methodology for calculating the scan MDC for alpha scans in its December 19, 2014, submittal (Cameco, 2014).

For alpha-emitting radionuclides, the scan MDC takes into account that the background response of most alpha detectors is very close to zero. At these low count rates, the probability of detecting alpha-emitting surface contamination is calculated using Poisson summation statistics. Equation 6-12 of NUREG-1575 describes the probability of observing a single count while passing the detector over a contaminated area (NRC, 2000). Abelquist (2014) defined the minimum alpha activity that can be detected by solving Equation 6-12 for "G", resulting in:

$$Alpha\ scan\ MDC = \frac{[-1n(1 - P(n \geq 1)] * 60}{\varepsilon_i \varepsilon_s t}$$

where: P (n ≥ 1) is the probability of detecting a single count;
ε_i is the instrument efficiency; and
$\varepsilon_s$is the surface efficiency; and t is the scan time (also referred to as residence time) in seconds.

For additional information see the discussion in NRC staff draft and final safety evaluations in NRC, 2015a, and NRC, 2015b, respectively.

NRC staff comment 10
If alpha scans will be used at the Crow Butte facility, please describe how the MDC will be calculated. In addition, after calculating radionuclide-weighted alpha counting efficiencies for the major radionuclide mixtures likely to be encountered at the Crow Butte Project, please demonstrate that the stated scan MDC value for alpha contamination on material and equipment can be met.

Crow Butte Response
As per Issue 6, this process will not be used and is being withdrawn from the submission.

Issue 11: Determining Alpha and Beta Instrument Efficiencies for the Ludlum Model 2929 counter or equivalent

Refer to the description of Issue 2 above for the calculation of MDC for stationary surveys.

Discussion
The NRC staff observes that there appears to be a typographical error on page 3 of 3 of Cameco, 2014, where Equation 3 (MDC) is labeled as Equation (1). The following equation is the subject of this issue:

$$MDC = \frac{3 + 3.29\sqrt{R_b\, t_g(1 + \frac{t_g}{t_b})}}{\varepsilon_i t_g}$$

Where: R_b= the background count rate
t_g = the sample count time
t_b = the background count time
ε_i = the instrument efficiency

Similar to Issue 2 above, the MDC calculation should take the source efficiency into account in deriving the MDC. Moreover, consistent with NUREG-1507 (NRC, 1998) (see, for example, the discussion on page 5-14) and NUREG-1575, Supplement 1 (NRC, 2009), a weighted total efficiency should be calculated for the expected mixture of radionuclides to be evaluated. As a minimum, this should include aged yellowcake and pregnant lixiviant. See also NRC staff RAI No.3 in NRC, 2015a.

NRC staff comment 11

Please provide the methodology for calculating radionuclide-weighted alpha and beta counting efficiencies for the major radionuclide mixtures likely to be encountered at the Crow Butte Project for the Ludlum Model 2929 counter or equivalent. This should include, at a minimum, radionuclide mixtures for pregnant lixiviant and aged yellowcake.

After calculating radionuclide-weighted alpha and beta counting efficiencies for the major radionuclide mixtures likely to be encountered at the Crow Butte Project, please demonstrate that the stated MDC values for alpha and beta contamination can be met for the Ludlum Model 2929 counter or equivalent.

Crow Butte Response

The methodology used in Issue 2 has been used to determine the radionuclide weighted alpha and beta counting (total) efficiencies will also be applied to instruments used for removable contamination. Note, recently Model 3030 detectors were purchased and have replaced the Model 2929's.

Tables 8 and 9 show an example of the calculation of the instrument efficiency for the Ludlum Model 3030. The instrument efficiency, ε_i, was calculated according to the method outlined in ISO 7503-1 (ISO, 1988), namely that ε_i = (measured counts (cpm) – background counts (cpm)) / source surface emission rate (dpm). The instrument efficiency for the Model 3030 is 63.3% for alpha and 44.9% for beta.

Table 8: Calibration Source Data

Source Isotope	Source ID	Source Activity (dpm)	Source Surface Emission (dpm)
Th-230	5261-04	8106	4053
Sr/Y-90	M2-099	182200	110400

Table 9: Instrument Efficiency Calculation

Source #	5261-04	M2-099
Alpha 60 min bkg	27	
Beta 60 min bkg		1693
	Alpha	Beta

Count 1	2507	49210
Count 2	2505	49258
Count 3	2573	49307
Count 4	2576	49319
Count 5	2572	49472
Count 6	2612	49278
Count 7	2642	48890
Count 8	2617	49499
Count 9	2526	48783
Count 10	2514	49295
Average cpm	2564.4	49231.1
Source Surface Emission (dpm)	4053	110400
Instrument Efficiency**	**63.3%**	**44.6%**
	**(radionuclide weighted)	

Using the activity weighted fractions for aged yellowcake from (NRC, 2015a) and those calculated for pregnant lixiviant in Issue 2, the mixture weighted total efficiencies were calculated for both materials for alpha and beta in Tables 10 and 11.

Table 10: Mixture Weighted Efficiencies for Aged Yellowcake

Isotope	Energy (MeV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
U-238	4.15	0.485	0.21	0.633	0.25	0.0161
U-238	4.20	0.485	0.79	0.633	0.25	0.0606
U-234	4.72	0.493	0.28	0.633	0.25	0.0218
U-234	4.77	0.493	0.72	0.633	0.25	0.0562
U-235	4.21	0.022	0.06	0.633	0.25	0.0002
U-235	4.37	0.022	0.17	0.633	0.25	0.0006
U-235	4.40	0.022	0.55	0.633	0.25	0.0019
U-235	4.60	0.022	0.05	0.633	0.25	0.0002

Alpha Counting Efficiency = 0.1577

Isotope	Energy (keV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
Th-234	103	0.489	0.21	0	0.25	0.0000
Th-234	193	0.489	0.79	0	0.25	0.0000
Pa-234m	2290	0.489	0.98	0.446	0.50	0.1069
Th-231	206	0.022	0.13	0	0.25	0.0000
Th-231	287	0.022	0.12	0	0.25	0.0000
Th-231	288	0.022	0.37	0	0.25	0.0000
Th-231	305	0.022	0.35	0	0.25	0.0000

Beta Counting Efficiency = 0.1069

Table 11: Mixture Weighted Efficiencies for Pregnant Lixiviant

Isotope	Energy (MeV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
U-238	4.15	0.391	0.21	0.633	0.25	0.0130
U-238	4.20	0.391	0.79	0.633	0.25	0.0489
U-234	4.72	0.396	0.28	0.633	0.25	0.0175
U-234	4.77	0.396	0.72	0.633	0.25	0.0451
U-235	4.21	0.018	0.06	0.633	0.25	0.0002
U-235	4.37	0.018	0.17	0.633	0.25	0.0005
U-235	4.40	0.018	0.55	0.633	0.25	0.0016
U-235	4.60	0.018	0.05	0.633	0.25	0.0001
Th-230	4.62	0.075	0.24	0.633	0.25	0.0028
Th-230	4.68	0.075	0.76	0.633	0.25	0.0090
Ra-226	4.60	0.121	0.06	0.633	0.25	0.0011
Ra-226	4.78	0.121	0.95	0.633	0.25	0.0182

Alpha Counting Efficiency = 0.1581

Isotope	Energy (keV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency

Th-234	103	0.443	0.21	0	0.25	0.0000
Th-234	193	0.443	0.79	0	0.25	0.0000
Pa-234m	2290	0.443	0.98	0.446	0.50	0.0968
Th-231	206	0.115	0.13	0	0.25	0.0000
Th-231	287	0.115	0.12	0	0.25	0.0000
Th-231	288	0.115	0.37	0	0.25	0.0000
Th-231	305	0.115	0.35	0	0.25	0.0000

Beta Counting Efficiency = 0.0968

In summary, the two mixture weighted efficiencies for alpha and beta are shown in Table 12, note this is based on the instrument efficiency calculation shown in Table 9.

Table 12: Summary of Instrument Weighted Efficiencies

Mixture	Radiation Type	Total Efficiency (NRC, 2015 method)
Aged Yellowcake	Alpha	15.8%
	Beta	10.7%
Pregnant Lixiviant	Alpha	15.8%
	Beta	9.7%

The following formula is used to calculated MDC; note this formula assumes the smear area is 100 cm^2.

$$MDC\left(\frac{DPM}{100cm^2}\right) = \frac{3 + 3.29\sqrt{R_b\, t_g(1 + \frac{t_g}{t_b})}}{\varepsilon_t t_g\, (\frac{swipe\ area(cm^2)}{100cm^2})}$$

where: R_b = the background count rate
t_g = the sample count time
t_b = the background count time
ε_t = total efficiency (instrument efficiency * source efficiency)

As with measurements taken with a contamination probe, it is difficult to know what the potential contaminant on a surface is outside of some specific conditions, therefore, as was discussed in Issue 2, under most conditions the most restrictive efficiency will be required. Therefore the lower of the radionuclide weighted efficiencies for alpha and beta will be used in this calculation. Using alpha and beta background count rates from Table 9 of 27 counts in 60 minutes and 1693 counts in 60 minutes, respectively, and a sample count time of 1 minutes, the MDC for alpha is 33 dpm/100 cm^2 and for beta is 213 dpm/100 cm^2.

General Comments

Issue 12: Source to detector distance

The distance between a source (i.e., area of contamination) and the detector may affect the instrument efficiency and, thus, MDC. (Refer to Section 4.2 of NRC, 1998, and p.8 of NRC, 2015b)
Discussion

The NRC staff has endorsed (Refer to Section 4.2 of NRC, 1998) the recommendation that a detector's efficiency be determined at a source-to-detector distance that is similar to the expected detector-to-surface spacing in the field.

NRC staff comment 12
Please describe the source-to-detector distance used for determining detector efficiency and how various individuals performing surveys will maintain a detector-to-surface spacing that is similar to that distance.

Crow Butte Response
Site procedures for monitoring for contamination will be updated to state that the probe face should be held at approximately 0.3 cm (1/8 inch) from the material being monitored.

If there are any further questions or concerns feel free to contact me at (308) 665–2215 ext. 122.

Sincerely,

Bob Tiensvold
Restoration Manager

Enclosure

cc: Deputy Director
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CBO- File

ec: CR-Electronic File

References

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Crow Butte Resources, Inc. (CBR)
d/b/a Cameco Resources
Crow Butte Operation

SURVEY PROGRAM FOR BETA/GAMMA CONTAMINATION

August 2017

SURVEY PROGRAM FOR BETA/GAMMA CONTAMINATION

The Survey Program for Beta/Gamma Contamination will be used for beta/gamma surveys of personnel and equipment exiting restricted areas at the Crow Butte facility to meet the requirements of 10 CFR Part 20, Subpart F. The program includes surface contamination detection capability (minimum detection concentration (MDC)) for radiation survey instruments, including scan MDC for portable instruments, used for contamination surveys to release equipment and materials for unrestricted use and for personnel contamination surveys. The detection capability in the scanning mode for alpha and beta radiation are in terms of dpm per 100 cm^2.

Training

The Survey Program for Beta/Gamma Contamination will be conducted by an RSO or a qualified HPT. The training will be included as part of New Employee Radiation Safety Training and Annual Refresher Training.

Survey Equipment

The following equipment will be used for personnel monitoring; either Ludlum model 177 counters and 43-5 probes or Ludlum model 2241 scalar/ratemeter or equivalents along with a 43-5 probes or equivalents will be used. For equipment alpha scanning, a Ludlum 2241 scaler/ratemeter or equivalent and, nominally, a 43-65 probe are used. There are several probes that are compatible with these meters that may be used in the future. If these meters are used with alternate compatible probes, the MDC will be verified by the RSO to ensure it meets the requirements. To meet the requirement for measurement of beta radiation, where ambient background conditions permit, monitoring for both alpha and beta radiation will be performed using a 2224 scaler/ratemeter or equivalent along with a 43-93 probe or equivalent equipment.

Personnel Surveys

Personnel leaving a restricted area will be required to perform alpha and beta/gamma surveys and record and sign the logs prior to exiting the area. At a minimum the hands and soles of the boots/shoes will be surveyed. The release limit for personnel scanning will be 1000 dpm/100 cm^2 for alpha and beta/gamma radiation. Scanning stations will be posted with the limit in terms of either the total counts allowed in specified time and/or count rate, depending on the available meter. The limits will be established based on routine background measurements taken at the scanning stations. If a reading above the limit occurs, decontamination and resurveying will be required along with notification to the RSO. Surveys of personnel will generally be performed using scalar, or integrated, counting instead of scanning.

The minimum detectable concentration (MDC) for scalar alpha and beta/gamma measurements using hand held probes will be determined based on the method in NUREG 1507, shown in equation (1).

$$MDC\left(\frac{DPM}{100cm^2}\right) = \frac{3 + 3.29\sqrt{R_b\, t_g(1 + \frac{t_g}{t_b})}}{\varepsilon_t t_g(\frac{SA}{100cm^2})} \tag{1}$$

where: R_b = the background count rate
t_g = the sample count time
t_b = the background count time
ε_t = the total efficiency (instrument efficiency * source efficiency)
SA = probe surface area (cm^2)

CBO will utilize the method described in (Strata Energy Inc., 2015) for calculating radionuclide-weighted alpha and beta counting efficiencies for the major radionuclide mixtures, namely aged yellowcake and pregnant lixiviant.

For aged yellowcake alpha emissions, CBO uses a certified NIST traceable natural uranium sources for determining alpha efficiencies of the hand held contamination monitoring equipment. The records are available on site for inspection. Because the source is identical in energy emissions to the alpha emitters from aged yellowcake (i.e. U238, U235 and U234 in natural abundance), the alpha instrument efficiencies calculated with this source are radionuclide-weighted efficiencies for aged yellowcake alpha emissions. No additional calculations are required for this radiation type and product. These sources have a 150 cm^2 surface area and the ratio between source and probe surface areas are included in the equipment efficiency calculation. A source efficiency of 0.25, as recommended by ISO 7503-1, will be used in combination with the instrument efficiency to calculate total efficiency. Table 2 below, shows an example of calculation of instrument efficiency using this source; the instrument efficiency was 35.9%. Multiplying that by the source efficiency of 25% results in a total efficiency of 9%.

For beta emissions from aged yellowcake, while use of the same natural uranium source would be ideal, because the uranium is in radioactive equilibrium with its short lived beta-emitting decay products, this source does not currently have an NIST traceable calibration certificate for beta emission. Therefore Sr/Y-90 and C14 sources, which are NIST traceable with records available on site for inspection, will be used to determine instrument efficiency for beta emissions and the methodology from (Strata Energy Inc., 2015) used to determine a total radionuclide weighted efficiency.

Tables 1 and 2 show an example of the calculation of the instrument efficiency for the Ludlum Model 43-93. The instrument efficiency, ε_i, was calculated according to the method outlined in ISO 7503-1 (ISO, 1988), namely that ε_i = (measured counts (cpm) – background counts (cpm)) / source surface emission rate (dpm). Note if the source area is greater than the probe area, source emissions (dpm) must be modified by ratio of (probe area/source area) to ensure the correct emissions are used. The instrument efficiency for the Model 43-93 is 35.9% for alpha (as per discussion above) and 52.2% for beta. It is important to note for clarity that the term 'source efficiency' as used by ISO 7503-1 refers to an actual alpha or beta contamination source (i.e. the object being measured for release), not to a reference source.

Table 1: Calibration Source Data

Source Isotope	**Source ID**	**Source Activity (dpm)**	**Source Surface Emission (dpm)**
U^{nat}	K1-076	23000	11390
Sr/Y-90	M2-098	189800	113800

Table 2: Instrument Efficiency Calculation

Source #	K1-076	M2-098
Total Activity (dpm)	11390	113800
Alpha 5 min bkg	31	
Beta 5 min bkg		1093
Source Size	150 cm^2	
Probe Size	100 cm^2	100 cm^2
	Alpha	Beta
Count 1	2657	59567
Count 2	2799	59632
Count 3	2772	59479
Count 4	2791	59319
Count 5	2747	60018
Count 6	2638	59449
Count 7	2781	59937
Count 8	2720	59637
Count 9	2671	59535
Count 10	2764	59924
Average cpm	2734	59649.7
Source Surface Emission (dpm)	11390	113800
Instrument Efficiency**	**35.90%**	**52.20%**
	**(radionuclide weighted)	

The radionuclide mixture weighted counting efficiency for beta for aged yellowcake was calculated using the methodology outlined in the draft (Strata Energy Inc., 2015) and is shown in Table 3. Because the lower energy beta emitters in aged yellowcake (i.e. Th-231 and Th-234) are not present in the Sr/Y 90 source, the instrument efficiency for these radionuclides will be assumed to be zero. The source for the uranium and activity fraction are NRC, 2015. The source for the energy and branching ratio are from Table 2-2 of DOE, 2009 (low yield radiations are not included). The total weighted beta efficiency for the Model 43-93 for aged yellowcake is 12.5%. As stated earlier the total weighted alpha instrument efficiency for aged yellowcake is 9.0%.

Table 3: Mixture Weighted Beta Efficiency for Aged Yellowcake for Model 43-93

Isotope	Energy (keV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
Th-234	103	0.489	0.21	0	0.25	0.0000
Th-234	193	0.489	0.79	0	0.25	0.0000
Pa-234m	2290	0.489	0.98	0.522	0.50	0.1251
Th-231	206	0.022	0.13	0	0.25	0.0000
Th-231	287	0.022	0.12	0	0.25	0.0000
Th-231	288	0.022	0.37	0	0.25	0.0000
Th-231	305	0.022	0.35	0	0.25	0.0000

Beta Counting Efficiency = 0.1251

The pregnant lixiviant is the process fluid which is returning from the wellfield to the plant, and will contain higher concentrations of radionuclides than the "barren lixiviant", or the process fluids which return to the wellfield after passing over the resin beds. In considering the mixtures, CBO has not taken into account radon gas (Rn-222) nor the short lived decay products of radon (radon daughters). Although the radon daughters are alpha and beta emitters, they were excluded from the calculations as the calculations are considering surface contamination levels, not airborne contamination levels.

Strata (Strata Energy Inc., 2015; hereon referred to as "Strata") provided a very detailed explanation as to the assumptions used to determine the radionuclide composition for pregnant lixiviant. Currently, no assays of the Crow Butte lixiviant are available, therefore the same assumptions as those in the approved Strata application will be used. Crow Butte Operation uses an alkaline based mining method similar to Stata and the referenced data sources. As such, the same assumptions will be adopted for CBO. Specifically, Strata identified (DOE, 2009) as the source for aged yellowcake composition and two sources of data were identified regarding the radionuclide composition in lixiviant (Brown, 1982 and LCI, 2015). The LCI, 2015 document contained a radionuclide composition analysis on pregnant lixiviant from a Uranium Recovery facility in Wyoming, using alkaline based mining techniques similar to that proposed by CBO. The LCI, 2015 document showed that the concentrations of the long-lived decay products of natural uranium in the pregnant lixiviant are negligible. Two radionuclides had elevated concentrations, namely Ra-226 and Th-234, with concentrations of 2,700 and 2,290 pCi/L respectively. Converting to Bq/L yields Ra-226 and Th-234 concentrations of 99.9 and 84.7 Bq/L respectively. The paper (Brown, 1982) lists concentrations for Th-230 and Ra-226. The concentration ranges for Th-230 are 56 - 93 Bq/L, and for Ra-226 are 10 - 150 Bq/L. To be conservative, the upper end of the higher concentrations, specifically 150 Bq/L for Ra-226 and 93 Bq/L for Th230, will be used for this analysis.

As there was no data regarding the concentrations of Th-231 and Pa-234m for the pregnant lixiviant, in alignment with the Strata application, CBO made the following estimations: for Th-231 and Pa-234m, it is assumed that Th-231 was in secular equilibrium with U-235 and Pa-234m was in secular equilibrium with Th-234. This estimation is valid as the half-lives of the parent radionuclides are much longer than the half-lives of the daughter radionuclides.

The activity fractions for pregnant lixiviant were calculated using the data and estimations listed above. The specific activity of 6.77E-7 Ci/g for natural Uranium was found in footnote (3) to Appendix B of 10 CFR 20. An average concentration of uranium in pregnant lixiviant is 25-30 ppm, and a conservative estimate of the concentration of uranium in the pregnant lixiviant which will be used is 40 ppm. Converting to Bq/L yields:

Concentration of U in pregnant lixiviant = 40 ppm = 40 mg/L = 0.04 g/L = 1E3 Bq/L

Therefore, the primary radionuclides of concern for contamination from pregnant lixiviant in regards to alpha and beta radiation are shown in Tables 4 and 5. Natural uranium, in Table 4, has been broken down by radionuclide according to natural abundance ratios.

Table 4: Primary Alpha Emitting Radionuclides in Lixiviant

	Bq/L	Fraction
U (total)	1,000	0.805
U-238	486	0.391
U-235	22	0.018
U-234	492	0.396
Th-230	93	0.075
Ra-226	150	0.121

Table 5: Primary Beta Emitting Radionuclides in Lixiviant

	Bq/L	Fraction
Th-234	84.7	0.443
Th-231	22	0.115
Pa-234m	84.7	0.443

Again following the process described in (NRC, 2015) the radionuclide mixture weighted counting efficiency was determined for lixiviant for both alpha and beta, shown in Tables 6. The instrument efficiencies were again taken from Table 2 and the default source efficiencies, as recommended by ISO 7503-1 were used. The source for the activity fractions are Strata Energy Inc., 2015, LCI, 2015, and Brown, 1982. The sources for the energy and branching ratio are from Table 2-2 of DOE, 2009 and the Health Physics and Radiological Health Handbook (1992) (low yield radiations are not included).

Because CBO does not have a traceable beta calibration source which emits beta particles at energies similar to the lower energy betas emitters (i.e. Th-231 and Th-234), the instrument efficiency for those radionuclides is listed as zero. The Y90 emission at 2.245 MeV is comparable to the 2.29 MeV emission of Pa-234m. To better account for the low energy emissions, a C-14 source will be purchased and the beta mixture efficiency recalculated at that time.

Table 6: Mixture Weighted Efficiencies for Pregnant Lixiviant.

Isotope	Energy (MeV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
U-238	4.15	0.391	0.21	0.359	0.25	0.0074
U-238	4.20	0.391	0.79	0.359	0.25	0.0277
U-234	4.72	0.396	0.28	0.359	0.25	0.0100
U-234	4.77	0.396	0.72	0.359	0.25	0.0256
U-235	4.21	0.018	0.06	0.359	0.25	0.0001
U-235	4.37	0.018	0.17	0.359	0.25	0.0003
U-235	4.40	0.018	0.55	0.359	0.25	0.0009
U-235	4.60	0.018	0.05	0.359	0.25	0.0001
Th-230	4.62	0.075	0.24	0.359	0.25	0.0016
Th-230	4.68	0.075	0.76	0.359	0.25	0.0051
Ra-226	4.60	0.121	0.06	0.359	0.25	0.0007
Ra-226	4.78	0.121	0.95	0.359	0.25	0.0103

Alpha Counting Efficiency = 0.0897

Isotope	Energy (keV)	Activity Fraction	Branching Ratio	Instrument Efficiency	Surface Efficiency	Weighted Efficiency
Th-234	103	0.443	0.21	0	0.25	0.0000
Th-234	193	0.443	0.79	0	0.25	0.0000
Pa-234m	2290	0.443	0.98	0.522	0.50	0.1133
Th-231	206	0.115	0.13	0	0.25	0.0000
Th-231	287	0.115	0.12	0	0.25	0.0000
Th-231	288	0.115	0.37	0	0.25	0.0000
Th-231	305	0.115	0.35	0	0.25	0.0000

Beta Counting Efficiency = 0.1133

In regards to the alpha efficiency for pregnant lixiviant, the same final efficiency can be achieved by simply multiplying the instrument efficiency (35.9%) by the source efficiency (25%). Therefore, for alpha efficiency determination, the simpler methodology of multiplying the instrument and source efficiency will be used for both yellowcake and lixiviant total efficiency calculations.

In summary, the two mixture weighted efficiencies for alpha and beta are shown in Table 7, note this is based on the instrument efficiency calculation shown in Table 2.

Table 7: Summary of Instrument Weighted Efficiencies

Mixture	Radiation Type	Total Efficiency (NRC, 2015 method)
Aged Yellowcake	Alpha	9.0%
	Beta	12.5%
Pregnant Lixiviant	Alpha	9.0%
	Beta	11.3%

While in some cases it may be possible to establish the actual nature of the contaminant on a surface, e.g. yellowcake drums; this would be the exception. In most cases, it will not be possible to conclusively say that a surface had the potential to be contaminated by only one form of material or another. In addition, trying to manage material specific efficiencies actually increases error potential due to the increased complexity of the process. Therefore, practically, the only reasonable option is to use the more restrictive efficiency unless it is possible to conclusively say what the contaminant is. Crow Butte will calculate the efficiency for both mixtures for its equipment, however in most cases it will be the more restrictive efficiency that is used for the calculations.

The requirements to be free of visible uranium and to meet the limit for alpha contamination prior to leaving the restricted area will reduce the potential for the spread of contamination outside of the restricted area. The monitoring will consist of a visual examination to detect any visible yellowcake and an alpha meter survey to ensure that any suspected contamination is below the acceptable limits. To eliminate the possibility of attenuated alpha particles from the scanning of wet boots, boot wash stations will not be utilized prior to exiting the restricted areas.

All contamination on skin and clothing is considered removable, so the limit of 1,000 dpm/100cm^2 is applied to personnel monitoring. If this limit is exceeded, personnel must decontaminate their skin and/or clothing and repeat the alpha survey. As stated in Regulatory Guide 8.30, if the action level is exceeded, the RSO will perform an investigation of the cause of the contamination and take corrective action if appropriate.

Personnel must complete the beta/gamma scanning process and be below the limit of 1000 dpm/100 cm^2 before entering the office areas, eating areas, or leaving the site. If the background beta/gamma count rate exceeds the allowed values, personnel will be required to pass the 1000 dpm/100 cm^2 limit for alpha contamination and then move to a lower background area within the controlled area to monitor for beta/gamma radiation.

Material & Equipment Surveys

For materials and equipment, Regulatory Guide 8.30 indicates the removable release limit is 1000 dpm/100cm^2, the average total activity limit is 5000 dpm/100cm^2 and the total maximum activity limit is 15,000 dpm/100 cm^2. Using the previously mentioned assumptions, if the background levels for beta/gamma reach 3450 counts in 5 minutes or 500 counts in 1 minute, this will result in MDCs of 745 dpm/100cm^2 and 741 dpm/100cm^2, respectively. If this background count rate is exceeded then smears will be required in order to release the equipment, as per existing site procedure, or the equipment will need to be moved to a lower background area within the controlled area for surveying. If contamination levels exceed 750 dpm/100cm^2, an alpha smear will be required. Prior to leaving the restricted zone, the equipment must meet the alpha release limits outlined in Regulatory Guide 8.30.

Surveys of materials and equipment will be performed by the RSO or a qualified HPT. Equipment must meet the limits for both alpha and beta contamination prior to being assigned controlled release status.

Though scanning is not the preferred method, it is a potential survey option. For instruments used in ratemeter mode, the beta/gamma MDC will be based on Regulatory Guide 1507. The beta/gamma scan MDC is calculated as follows:

$$Scan\ MDC\left(\frac{DPM}{100cm^2}\right) = \frac{d'\left(\frac{60}{t_s}\right)\sqrt{b_i\left(\frac{t_s}{60}\right)}}{\sqrt{p}\epsilon_i\epsilon_s\frac{Probe\ Area}{100\ cm^2}} \quad (2)$$

Where: t_s = Scan time (sec)
d' = level of performance (Table 6.1 from NUREG 1507) (false positive portion =0.6, true positive = 0.95)
b_i = average number of bkg counts in interval (cpm)
p = surveyor efficiency; assumed 0.5
ϵ_i = instrument efficiency (18%)
ϵ_s = surface efficiency (0.5) from section 5 of NUREG 1507

From NUREG-1575, the level of performance value, d', will be 1.38. This is based on a true positive proportion of 0.95 and false positive portion of 0.60. As described above, the beta/gamma efficiency of 18% will be used in the nominal MDC calculations. The surface efficiency is 0.50, based on the beta emission energy of 2.195 MeV from Pa234m, the primary beta emitter of Uranium 238. The planned scan rate is 1 cm/sec. With a 15 cm probe length, this scan rate equates to a scan time of 15 seconds. Using this method, a background count rate of 575 cpm will result in an MDC of 750 dpm/100cm^2. If the background count rate is exceeded, either smears will be required in order to release the equipment or the equipment will need to be moved to a low background area within the controlled area and resurveyed. If a different scanning rate is used, the MDC will be recalculated based on actual values.

In rooms where work with uranium is not performed, a lower level of surface contamination is likely to be present such as eating rooms, change rooms, control rooms, and offices. Therefore, weekly spot checks will be performed for removable surface contamination using smear tests. All eating rooms, change rooms, control rooms, and offices will be spot checked monthly. If surface contamination levels exceed the values shown in Regulatory Guide 8.30, Table 2, the RSO will be notified and the contaminated area will be promptly cleaned and resurveyed.

The instrument used to quantify removable beta/gamma contamination is the Ludlum model 2929 counter or an equivalent. The typical efficiency for this instrument is 25%. A background count will be taken daily prior to use for 50 minutes and samples will be counted for 1 minute. Using the equation (3), to achieve an MDC of 250 dpm/100 cm^2, the background count must be below 15,000 counts in 50 minutes. Actual MDC values will be calculated based on measured instrument efficiencies.

$$MDC = \frac{3+3.29\sqrt{R_b\, t_g(1+\frac{t_g}{t_b})}}{\varepsilon_i t_g} \quad (3)$$

Where: R_b = the background count rate
t_g = the sample count time
t_b = the background count time
ε_i = the instrument efficiency

Controlled Area

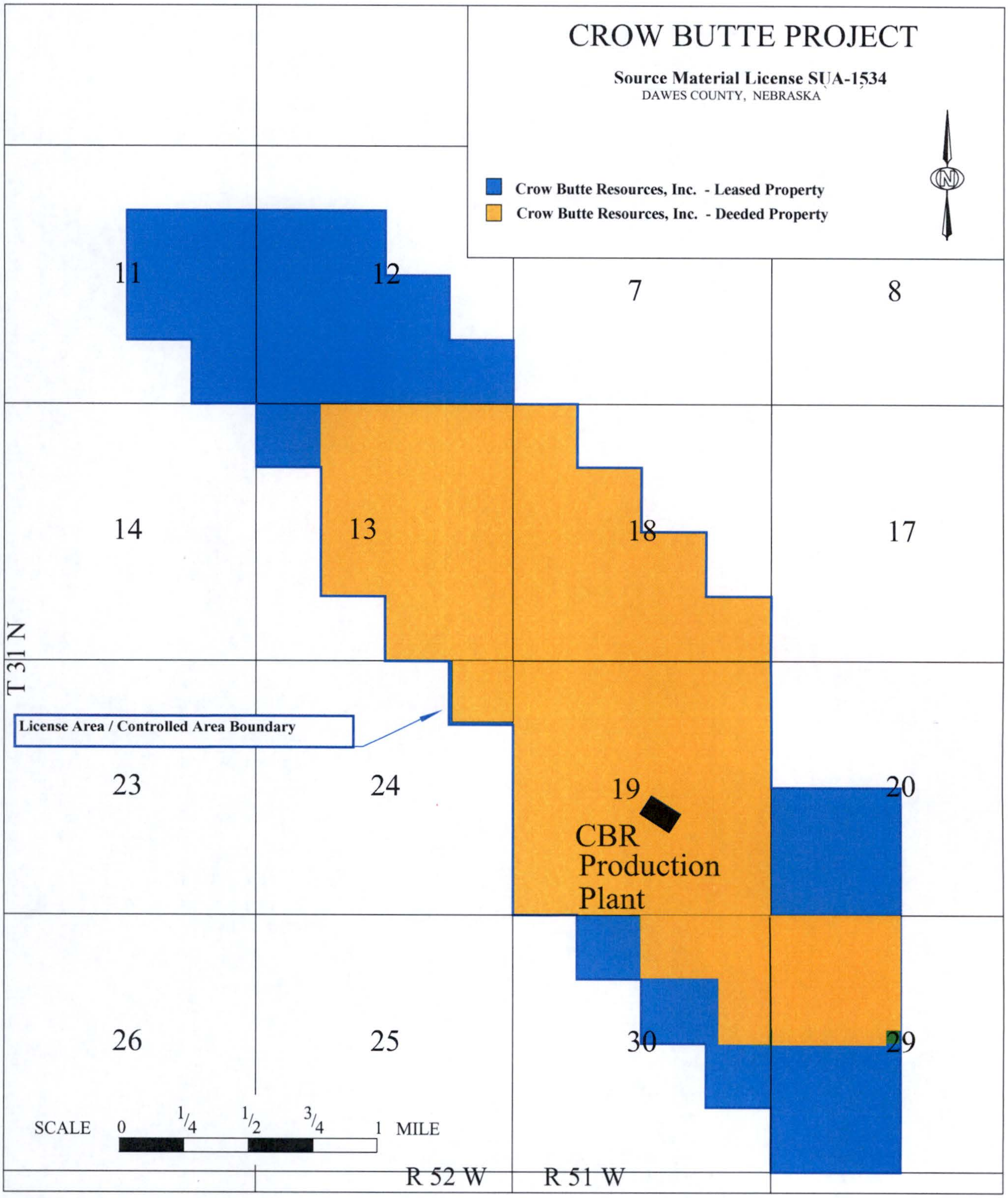
Crow Butte Resources, Inc. has the right and ability to carry out mining operations within the license boundaries as described in Source Material License 1534 (Renewed November 2014). CBR has the right to control access to areas within the license boundary. Controlling access is done for both a safety and operational standpoint to protect CBR employees and members of the public. CBR has the right to remove any person who has not been through CBR's required training or does not have permission from CBR to be in the controlled area. CBR has defined the controlled areas as all areas within the license boundary as shown on the map behind Appendix A. Proof of ownership and proof of control over leased lands are also included in Appendix A.

By definition in 10 CFR Part 20 Subpart A, a controlled area is defined as an area outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason. As described above, CBR has right to remove anyone from inside the license boundary and has designated the entire area within the license boundary as a controlled area.

In circumstances were materials and equipment are moved from a restricted area and the background count rate is exceeded the materials and equipment will need to be moved to a low background area within the controlled area and surveyed for free release. The free release surveys will be conducted in areas immediately adjacent to the Central Processing Plant, R.O. Building and Maintenance Building. No materials or equipment that have not been surveyed for free release will be allowed to be stored in the controlled area.

Personnel leaving a restricted area will be required to perform alpha and beta/gamma surveys and record and sign the logs prior to exiting the area. If personnel are required to move through the controlled area to perform the required survey they may not enter into the office area, lunchroom or their personal vehicles prior to performing the alpha and beta/gamma surveys.

APPENDIX A



CROW BUTTE PROJECT
Source Material License SUA-1534
DAWES COUNTY, NEBRASKA
N
Crow Butte Resources, Inc. - Leased Property
Crow Butte Resources, Inc. - Deeded Property
11
12
7
8
14
13
18
17
T 31 N
License Area / Controlled Area Boundary
23
24
19
20
CBR
Production
Plant
26
25
30
29
SCALE 0 1/4 1/2 3/4 1 MILE
R 52 W
R 51 W

DAWES COUNTY ASSESSOR'S OFFICE
451 MAIN STREET
CHADRON, NEBRASKA 69337
(308) 432-0103 FAX: (308) 432-3150
EMAIL: DAWESCOUNTYASSESSOR@YAHOO.COM
WEBSITE: WWW.CO.DAWES.NE.US

Roberta "Lindy" Coleman
Assessor

Cheryl Dunn
Deputy Assessor

August 1, 2017

Crow Butte Resources
Attn: Larry Teahon
P.O. Box 169
Crawford, NE 69337

Re: Property owned by Crow Butte Resources

Dear Larry,

As per our conversation this morning, attached you will find the 2017 Real Estate Breakdown Report for all parcels on the tax rolls in Dawes County owned by Cameco Resources, it's sister companies and subsidiaries commonly referred to as Crow Butte.

Please let me know if you have any questions.

Sincerely,

Lindy Coleman
Dawes County Assessor

ENCLOSURES

DAWES COUNTY

2017 Real Estate Breakdown Report

Parcel ID 230001868

Owner
CROW BUTTE LAND CO
DBA CAMECO RESOURCES
CHRISTINA GIFFIN
550 N. POPLER ST SUITE 100
CASPER, WY 82601

Card File

Legal
N2SW4
S-T-R: 29-31-51 Acres: 80.000

Situs

County Area	3	Market Area 3
Neighborhood	2000	RURAL
Location / Group	0	DEFAULT
District	711	71F4
School	23-0071	
Class Code	02-03-03-03-00-09	
State GEO	0000-00-0-00000-000-0000	
Cadastral	-	
Book / Page	/	
Sale Date		
Sale Amount	0	

Value	Previous	Current
Buildings	0	0
Improvement	0	0
Land / Lot	120,000	120,000
Total	120,000	120,000

Soil	Use	LCG/LVG	LCG/LVG Description	Spot	Code	Acres	Value/Acre	Assessed	Sub
STL	STL	STL	STL	N		80.000	1,500	120,000	10
					Land Total	80.000		120,000	

Year	Statement	District	Building	Other	Land	Total	Exempt	Taxable	Total Tax	Penalty Tax
2016	1231	711	0	0	120,000	120,000	0	120,000	1,750.36	0
2015	1240	711	0	0	120,000	120,000	0	120,000	1,725.50	0

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DAWES COUNTY

2017 Real Estate Breakdown Report

Parcel ID 230001867

Owner
CROW BUTTE LAND COMPANY
DBA CAMECO RESOURCES
CHRISTINA GIFFIN
550 N. POPLER ST SUITE 100
CASPER, WY 82601

Card File

Legal
NW4
S-T-R: 29-31-51 Acres: 160.000

Situs

County Area	3	Market Area 3
Neighborhood	2000	RURAL
Location / Group	0	DEFAULT
District	711	71F4
School	23-0071	
Class Code	02-03-03-03-00-09	
State GEO	0000-00-0-00000-000-0000	
Cadastral	--	
Book / Page	2009 / 672	
Sale Date	05/08/2009	
Sale Amount	160,000	

Value	Previous	Current
Buildings	0	0
Improvement	0	0
Land / Lot	240,000	240,000
Total	240,000	240,000

Soil	Use	LCG/LVG	LCG/LVG Description	Spot	Code	Acres	Value/Acre	Assessed	Sub
STL	STL	STL	STL	N		160.000	1,500	240,000	10
					Land Total	160.000		240,000	

Sale Date	Book	Page	Extend	Ownership History	Amount
				EHLERS,ROY DEAN	0

Year	Statement	District	Building	Other	Land	Total	Exempt	Taxable	Total Tax	Penalty Tax
2016	1237	711	0	0	240,000	240,000	0	240,000	3,500.68	0
2015	1246	711	0	0	240,000	240,000	0	240,000	3,451.00	0

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DAWES COUNTY

2017 Real Estate Breakdown Report

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Parcel ID 230001875

Owner
CROW BUTTE LAND COMPANY
DBA CAMECO RESOURCES
CHRISTINA GIFFIN
550N. POPLER ST SUITE 100
CASPER, WY 82601

Card File

Legal
PT E2, PT NW4
S-T-R: 30-31-51 Acres: 105.930

Situs

County Area	3	Market Area 3
Neighborhood	2000	RURAL
Location / Group	0	DEFAULT
District	711	71F4
School	23-0071	
Class Code	02-03-03-03-00-10	
State GEO	0000-00-0-00000-000-0000	
Cadastral	--	
Book / Page	2010 / 116	
Sale Date	01/27/2010	
Sale Amount	70,000	

Value	Previous	Current
Buildings	0	0
Improvement	0	0
Land / Lot	155,145	155,145
Total	155,145	155,145

Soil	Use	LCG/LVG	LCG/LVG Description	Spot	Code	Acres	Value/Acre	Assessed	Sub
ROAD	ROAD	ROAD	ROAD	N		2.500	0	0	10
STL	STL	STL	STL	N		103.430	1,500	155,145	10
					Land Total	105.930		155,145	

Year	Statement	District	Building	Other	Land	Total	Exempt	Taxable	Total Tax	Penalty Tax
2016	1238	711	0	0	155,145	155,145	0	155,145	2,262.98	0
2015	1247	711	0	0	155,145	155,145	0	155,145	2,230.86	0

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DAWES COUNTY

2017 Real Estate Breakdown Report

Parcel ID	230001835	Legal
Owner		W2W2, E2W2, SE4 E OF RR EXCEPT 3.84 ACRES
	CROW BUTTE LAND COMPANY CAMECO RESOURCES 550 NORTH POPLAR, SUITE 100 CASPER, WY 82601	S-T-R: 19-31-51 Acres: 480.740
Card File		Situs

County Area	3	Market Area 3
Neighborhood	0	N/A
Location / Group	0	DEFAULT
District	711	71F4
School	23-0071	
Class Code	02-05-05-03-00-10	
State GEO	0000-00-0-00000-000-0000	
Cadastral	--	
Book / Page	2011 / 1332	
Sale Date	11/14/2011	
Sale Amount	550,000	

Value	Previous	Current
Buildings	0	0
Improvement	0	0
Land / Lot	337,155	338,325
Total	337,155	338,325

Soil	Use	LCG/LVG	LCG/LVG Description	Spot Code	Acres	Value/Acre	Assessed	Sub
FBLDG	FBLDG	FBLDG	FARM BLDG SITE	N	1.000	2,000	2,000	10
1014	GRAS	4G	4G	N	31.990	741	23,705	10
5070	GRAS	3G1	3G1	N	102.050	793	80,925	10
5129	GRAS	4G	4G	N	28.920	741	21,430	10
5143	GRAS	4G	4G	N	220.030	741	163,040	10
5254	GRAS	4G	4G	N	1.530	741	1,135	10
5964	GRAS	4G1	4G1	N	27.580	741	20,435	10
6028	GRAS	4G	4G	N	3.330	741	2,470	10
6090	GRAS	4G	4G	N	28.680	741	21,250	10
					444.110		334,390	
ROAD	ROAD	ROAD	ROAD	N	16.270	0	0	10
5070	WATER	WASTE	WASTE	N	4.060	100	405	10
5129	WATER	WASTE	WASTE	N	0.880	100	90	10
5143	WATER	WASTE	WASTE	N	14.060	100	1,405	10
5964	WATER	WASTE	WASTE	N	0.360	100	35	10
					19.360		1,935	
				Land Total	480.740		338,325	

Sale Date	Book	Page	Extend	Ownership History	Amount
01/23/2007	2009	1168		STETSON,LAVERNE & SHANLEY,JEWELL M	0

Year	Statement	District	Building	Other	Land	Total	Exempt	Taxable	Total Tax	Penalty Tax
2016	1236	711	0	0	337,155	337,155	0	337,155	4,917.80	0
2015	1245	711	0	0	318,810	318,810	0	318,810	4,584.22	0

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DAWES COUNTY

2017 Real Estate Breakdown Report

Parcel ID	230001838	Legal
Owner		ALL
	CROW BUTTE RESOURCES,INC DBA CAMECO RESOURCES CHRISTINA GIFFIN 550 N. POPLER ST SUITE 100 CASPER, WY 82601	S-T-R: 19-31-51
Card File		Situs

County Area	3	Market Area 3
Neighborhood	2000	RURAL
Location / Group	0	DEFAULT
District	711	71F4
School	23-0071	
Class Code	02-09-07-03-00-00	
State GEO	0000-00-0-00000-000-0000	
Cadastral	--	
Book / Page	/	
Sale Date		
Sale Amount	0	

Value	Previous	Current
Buildings	0	0
Improvement	0	0
Land / Lot	4,549,238	3,585,321
Total	4,549,238	3,585,321

Year	Statement	District	Building	Other	Land	Total	Exempt	Taxable	Total Tax	Penalty Tax
2016	1244	711	0	0	4,549,238	4,549,238	0	4,549,238	66,356.04	0
2015	1252	711	0	0	6,612,245	6,612,245	0	6,612,245	95,078.68	0

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Parcel ID	230001975	**Legal**	E2, E2NW4, NE4SW4, NW4NW4 S-T-R: 13-31-52
Owner	CROW BUTTE RESOURCES,INC DBA CAMECO RESOURCES CHRISTINA GIFFIN 550 N. POPLER ST SUITE 100 CASPER, WY 82601	**Situs**	
Card File			

County Area	3	Market Area 3
Neighborhood	2000	RURAL
Location / Group	0	DEFAULT
District	711	71F4
School	23-0071	
Class Code	02-09-07-03-00-00	
State GEO	0000-00-0-00000-000-0000	
Cadastral	--	
Book / Page	/	
Sale Date		
Sale Amount	0	

Value	Previous	Current
Buildings	0	0
Improvement	0	0
Land / Lot	3,141,141	2,475,579
Total	3,141,141	2,475,579

Year	Statement	District	Building	Other	Land	Total	Exempt	Taxable	Total Tax	Penalty Tax
2016	1250	711	0	0	3,141,141	3,141,141	0	3,141,141	45,817.28	0
2015	1258	711	0	0	4,565,598	4,565,598	0	4,565,598	65,649.56	0

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2017 Real Estate Breakdown Report

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Parcel ID	230002004	**Legal**	NE4NE4 S-T-R: 24-31-52
Owner	CROW BUTTE RESOURCES,INC DBA CAMECO RESOURCES CHRISTINA GIFFIN 550 N. POPLER ST SUITE 100 CASPER, WY 82601	**Situs**	
Card File			

County Area	4	Market Area 4
Neighborhood	2000	RURAL
Location / Group	0	DEFAULT
District	711	71F4
School	23-0071	
Class Code	02-09-07-03-00-00	
State GEO	0000-00-0-00000-000-0000	
Cadastral	--	
Book / Page	/	
Sale Date		
Sale Amount	0	

Value	Previous	Current
Buildings	0	0
Improvement	0	0
Land / Lot	0	0
Total	0	0

Year	Statement	District	Building	Other	Land	Total	Exempt	Taxable	Total Tax	Penalty Tax
2016	1251	711	0	0	0	0	0	0	0.00	0
2015	1259	711	0	0	0	0	0	0	0.00	0

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2017 Real Estate Breakdown Report

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Parcel ID	230001874	**Legal**	NE4, NE4SE4, NE4NW4, S-T-R: 30-31-51
Owner	CROW BUTTE RESOURCES,INC DBA CAMECO RESOURCES CHRISTINA GIFFIN 550 N. POPLER ST SUITE 100 CASPER, WY 82601	**Situs**	
Card File			

County Area	3	Market Area 3
Neighborhood	2000	RURAL
Location / Group	0	DEFAULT
District	711	71F4
School	23-0071	
Class Code	02-09-07-03-00-00	
State GEO	0000-00-0-00000-000-0000	
Cadastral	--	
Book / Page	/	
Sale Date		
Sale Amount	0	

Value	Previous	Current
Buildings	0	0
Improvement	0	0
Land / Lot	1,191,467	939,013
Total	1,191,467	939,013

Year	Statement	District	Building	Other	Land	Total	Exempt	Taxable	Total Tax	Penalty Tax
2016	1247	711	0	0	1,191,467	1,191,467	0	1,191,467	17,378.96	0
2015	1255	711	0	0	1,731,778	1,731,778	0	1,731,778	24,901.54	0

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DAWES COUNTY

2017 Real Estate Breakdown Report

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Parcel ID	230001871		**Legal**				
Owner			W2				
CROW BUTTE RESOURCES,INC DBA CAMECO RESOURCES CHRISTINA GIFFIN 550 N. POPLER ST SUITE 100 CASPER, WY 82601			S-T-R: 29-31-51				
Card File			**Situs**				
County Area	3	Market Area 3	**Value**		**Previous**	**Current**	
Neighborhood	2000	RURAL	**Buildings**		0	0	
Location / Group	0	DEFAULT	**Improvement**		0	0	
District	711	71F4	**Land / Lot**		1,137,310	896,330	
School	23-0071		**Total**		1,137,310	896,330	
Class Code	02-09-07-03-00-00						
State GEO	0000-00-0-00000-000-0000						
Cadastral	--						
Book / Page	/						
Sale Date							
Sale Amount	0						

Year	Statement	District	Building	Other	Land	Total	Exempt	Taxable	Total Tax	Penalty Tax
2016	1246	711	0	0	1,137,310	1,137,310	0	1,137,310	16,589.02	0
2015	1254	711	0	0	1,653,061	1,653,061	0	1,653,061	23,769.66	0

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DAWES COUNTY

2017 Real Estate Breakdown Report

Page 1
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Parcel ID	230001846		**Legal**				
Owner			SW4				
CROW BUTTE RESOURCES,INC DBA CAMECO RESOURCES CHRISTINA GIFFIN 550 N. POPLER ST SUITE 100 CASPER, WY 82601			S-T-R: 20-31-51				
Card File			**Situs**				
County Area	3	Market Area 3	**Value**		**Previous**	**Current**	
Neighborhood	2000	RURAL	**Buildings**		0	0	
Location / Group	0	DEFAULT	**Improvement**		0	0	
District	711	71F4	**Land / Lot**		0	0	
School	23-0071		**Total**		0	0	
Class Code	02-09-07-03-00-00						
State GEO	0000-00-0-00000-000-0000						
Cadastral	--						
Book / Page	/						
Sale Date							
Sale Amount	0						

Year	Statement	District	Building	Other	Land	Total	Exempt	Taxable	Total Tax	Penalty Tax
2016	1245	711	0	0	0	0	0	0	0.00	0
2015	1253	711	0	0	0	0	0	0	0.00	0

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DAWES COUNTY

2017 Real Estate Breakdown Report

Page 1
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Parcel ID	230001833		**Legal**				
Owner			SW4, S2NW4, NW4NW4, S2SE4, NW4SE4				
CROW BUTTE RESOURCES,INC DBA CAMECO RESOURCES CHRISTINA GIFFIN 550 N. POPLER ST SUITE 100 CASPER, WY 82601			S-T-R: 18-31-51				
Card File			**Situs**				
County Area	3	Market Area 3	**Value**		**Previous**	**Current**	
Neighborhood	2000	RURAL	**Buildings**		0	0	
Location / Group	0	DEFAULT	**Improvement**		0	0	
District	711	71F4	**Land / Lot**		1,787,201	1,408,519	
School	23-0071		**Total**		1,787,201	1,408,519	
Class Code	02-09-07-03-00-00						
State GEO	0000-00-0-00000-000-0000						
Cadastral	--						
Book / Page	/						
Sale Date							
Sale Amount	0						

Year	Statement	District	Building	Other	Land	Total	Exempt	Taxable	Total Tax	Penalty Tax
2016	1242	711	0	0	1,787,201	1,787,201	0	1,787,201	26,068.46	0
2015	1250	711	0	0	2,597,668	2,597,668	0	2,597,668	37,352.32	0

AFFIDAVIT OF FACT

STATE OF WYOMING §
§
COUNTY OF Converse §

I, Doug Pavlick, General Manager, US Operations, confirm that the information pertaining to the mining lease agreements described herein and lands owned in fee by Crow Butte Land Company, a wholly owned subsidiary of Crow Butte Resources, Inc. are true and correct. Said agreements give Crow Butte Resources the right to mine the lands and control access thereto.

[signature]
Doug Pavlick, General Manager, US Operations

Subscribed and sworn to before me this 3rd day of August, 2017

Kimberly Weisenberger
Notary Public

My Commission Expires: Oct 24, 2018

Kimberly Weisenberger - Notary Public
County of Converse
State of Wyoming
My Commission Expires October 24, 2018

LANDS CONTROLLED BY MINING LEASE AGREEMENTS
WITHIN THE MINING PERMIT

MINING LEASE	**LEGAL DESCRIPTION**
Date: October 19, 1977 Lessor: Robert H. & Lottie C. McDowell, H/W Lessee: Bruce L. Bump Current Lessor/surface owner: McDowell Family Trust Mary C. McDowell Trust Current Lessee: Crow Butte Land Company	Township 31 North, Range 52 West Section 12: SW/4, S/2NW/4, S/2SE/4
Date: April 20, 1984 Lessor: Don C. & De Lila Reynoldson, H/W Lessee: Wyoming Fuel Corporation Current Lessor/surface owner: Donald & De Lila Trust Current Lessee: Crow Butte Land Company	Township 31 North, Range 52 West Section 11: S/2NE/4
Date: January 15, 1980 Lessor: Lorentz F. & Martha M. Raben H/W Lessee: Wyoming Fuel Corporation Current Lessor/surface owner: Raben Ranch, LLC Current Lessee: Crow Butte Land Company	Township 31 North, Range 52 West Section 11: N/2SE/4, SE/4SE/4
Date: June 29, 2013 Lessor: John E. & Janet Dodd H/W, David L. Dodd, Mima Lue Dodd, Kalvin Dodd Lessee: Crow Butte Land Company Current Lessor/surface owner: Kalvin Dodd Current Lessee: Crow Butte Land Company	Township 31 North, Range 52 West Section 13: NW/4NW/4
Date: January 4, 1978 Lessor: Orville E. & Anna H. Stetson, H/W Lessee: Bruce L. Bump Current Lessor/surface owner: Stetson Ranch, LLC Current Lessee: Crow Butte Land Company	Township 31 North, Range 51 West Section 18: Lots 1 thru 4, SE/4NW/4, E/2SW/4, S/2SE/4, NW/4SE/4 Section 19: Part of SW/4 lying West of R/R
Date: October 10, 1980 Lessor: Frank A. & Mabel L. Ehlers, H/W Lessee: Wyoming Fuels Corporation Current Lessor/surface owner: Sharyn Thompson Current Lessee: Crow Butte Land Company	Township 31 North, Range 51 West Section 20: W/2SW/4
Date: July 8, 2002 Lessor: Mike & Beverly Dyer, H/W Lessee: Crow Butte Land Company Current Lessor/surface owner: : Mike & Beverly Dyer Current Lessee: Crow Butte Land Company	Township 31 North, Range 52 West Section 24: NE/4NE/4

Date: December 1, 1990
Lessor: Warren G. Broyles Trust
Lessee: Crow Butte Land Company
Current Lessor/surface owner: : Mike & Beverly Dyer
Current Lessee: Crow Butte Land Company

Township 31 North, Range 51 West
Section 29: S/2SW/4
Section 30: That part of the NE/4, NE/4NW/4, NE/4SE/4, lying West of a survey line

LANDS OWNED IN FEE BY CROW BUTTE LAND COMPANY
WITHIN THE MINING PERMIT

Township 31 North, Range 52 West
Section 13: E/2, E/2NW/4. NE/4SW/4

Township 31 North Range 51 West
Section 19: E/2, NW/4, Part of SW/4 lying East of R/R
Section 29: NW/4, N/2SW/4
Section 30: That part of the NE/4, NE/4NW/4, NE/4SE/4, lying East of a survey line.