Annual ALARA Audit Report for 2014

Crow Butte Operations

Prepared for:

Cameco Crow Butte Operations

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EXECUTIVE SUMMARY

In year one of a three year audit cycle, an ALARA Audit of the Crow Butte Operations (CBO) in situ uranium recovery facility was conducted by Two Lines, Inc. and Cameco on February 24-27, 2015. The audit commenced with an opening meeting on Tuesday, February 24 led by the auditors, Drs. Craig Little and Jan Johnson, CHP. A close out meeting at which preliminary audit results were presented was held on Friday morning, February 27. The ALARA audit was conducted in conjunction with a radiation and transportation regulatory compliance audit.

For purposes of the ALARA audit, numerous records were examined prior to and during the audit visit including those shown in the table below.

Environmental Health and Safety Manual
Nuclear Regulatory Commission inspection reports
Previous audit reports
RSO and HPT training Records
Annual radiation worker training records
Visitor orientation records
Bioassay laboratory reports
Worker dosimetry reports
Radon decay product measurements
Air particulate measurement data
Routine inspection logs (daily walk through and weekly RSO inspection)
Monthly RSO reports
SERP records
Monthly Safety Meeting records
Quarterly RSO staff performance review
Survey instrument calibration records
On-site lab survey records – check on the lab
RWPs
Semi-annual environmental monitoring reports
Environmental gamma measurement data
Environment air particulate concentrations
Respirator program

Cameco personnel were very helpful in conducting this audit. The auditors were impressed with the availability and condition of the records. Records requested were immediately produced and were generally in excellent condition. Much of the requested information is available in electronic form. The filing system for hard copy information is easily accessible to the staff with whom the auditors interacted.

The maximum occupational dose for 2014 was 0.437 rem for a dryer operator. The average TEDE for 2014 was 0.164 rem. This is similar to the average TEDE for 2013. No findings of violations were noted. The radiation safety data, including the dose records, are entered into Cameco's CAMRAD database. The trends in average and maximum annual doses prepared by Cameco from the CAMRAD database are shown in Appendix A.

The estimated dose to the nearest resident member of the public from inhalation of uranium was 0.04 mrem/y. The annual average measured concentrations of Ra-226 and Pb-210 at that location were less than the measured concentrations at the background monitoring station. The net annual average radon concentration was 1 E-10 µCi/mL, equal to the effluent standard for Rn-222 in equilibrium with its decay products. The estimated dose from radon decay products was 50 mrem/y. The net total gamma dose for the year 2014 was 2.6 mrem for a total effective dose equivalent (TEDE) of 52.6 mrem, which is below the 10 CFR 20.1301 dose limit for members of the public.

The ALARA report is divided into fourteen sections having to do with various aspects of the facility's operation as shown in the following table.

Report Section	Audit Records Discussed
2.1	Routine operations (Bioassay data, internal doses, external doses
2.2	Safety meeting minutes, attendance records, training program
2.3	Inspection reports
2.4	Radiological survey and monitoring data
2.5	Radiation work permits
2.6	Environmental Radiological Effluent and surveillance data
2.7	Instrument calibration records
2.8	Review of operating procedures
2.9	Source leak tests
2.10	Review of radiation protection records
2.11	Unusual events
2.12	Review of 2013 ALARA Audit findings and recommendations
3.0	Summary of 2014 audit findings and recommendations
4.0	References

No findings of violation were noted during the audit. A total of 13 recommendations for improvement were developed. Three best practices were observed.

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LIST OF ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
µCi	Microcurie
µg/L	Microgram per liter
ALARA	As Low As Reasonably Achievable
ALI	Annual Limit of Intake
APR	Air Purifying Respirator
Bq/m^3	Becquerel per cubic meter
CBO	Crow Butte Operations
CEDE	Committed Effective Dose Equivalent
Ci	Curie
CPP	Central Processing Plant
DAC	Derived Air Concentration
HPT	Health Physics Technician
ICRP	International Commission on Radiological Protection
keV	Thousand electron volts
ND	Non detect
NRC	Nuclear Regulatory Commission
NVLAP	National Voluntary Laboratory Accreditation Program
OSHA	Occupational Safety and Health Administration
OSL	Optically Stimulated Luminescent (Dosimeter)
pCi/L	Picocuries per liter
RML	Radioactive Materials License
RPF	Respirator Protection Factor
RSO	Radiation Safety Officer
RWP	Radiation Work Permit
SERP	Safety and Environment Review Panel
TEDE	Total Effective Dose Equivalent
WL	Working Level – measure of the concentration of radon decay products

1.0 INTRODUCTION

The 2014 ALARA Audit at the Crow Butte Operations (CBO) in situ uranium recovery facility was conducted by Two Lines, Inc. and Cameco on February 24-27, 2015. The audit commenced with an opening meeting on Tuesday, February 24 led by the auditors, Drs. Craig Little and Jan Johnson, CHP. A close out meeting at which preliminary audit results were presented was held on Friday morning, February 27. Attendees at the kick off and close out meetings are shown in Table 1.

Table 1. Attendees at Crow Butte audit meetings.

Name	Kick-off Meeting	Close Out Meeting
Auditors		
Janet A. Johnson	X	X
Craig A. Little	X	X
Cameco Corporate		
Morgan Bradford	X	
Merlin "Skeeter" Seier	X	X
Crow Butte Operations		
Steven Boeselager	X	X
Tami Dyer	X	X
Sabrina Fox	X	X
Tate Hagman		X
Gabe Scoggin		X
Larry Teahon	X	X
Bob Tiensvold		X
Kevin Vogl	X	X
Casey Yada	X	X

A tour of the Central Processing Plant (CPP) and the Reverse Osmosis facility (RO) was conducted by Kevin Vogl, Plant Foreman accompanied by Tami Dyer, RSO. The auditors were pleased with the general housekeeping in the plant and RO areas. There was a notable absence of tripping hazards on the floor. Areas where water was visible on the surface were the result of routine wash down procedures. Due to time constraints, the tour did not include the well fields.

Cameco personnel were very helpful in conducting this audit. The auditors were impressed with the availability and condition of the records. Records requested were immediately produced and were generally in excellent condition.

1.1 Site History

Commercial operations at the Crow Butte commenced in April 1991. The in situ recovery process extracts uranium from the Basal Chadron sandstone aquifers at a depth of approximately 400 to 800 feet below the ground surface. The uranium in the formations is leached by a solution pumped through injection wells. The uranium-rich solution is pumped

through recovery wells to the CPP where the uranium is extracted by ion exchange, precipitated, and dried in a "zero emissions" vacuum dryer. The purified uranium product (yellowcake) is packaged in 55 gallon drums and transported to the Blind River refinery in Port Hope, Ontario for chemical processing. Based on the process used for drying the precipitate and laboratory data, the uranium product is classified as "soluble" for the purpose of radiation protection.

Liquid waste from the plant, primarily "bleed" water is disposed of in the evaporation ponds or through deep well injection. Solid waste (11e2 byproduct) is transported to the White Mesa uranium facility in Blanding, Utah under a contract for disposal.

Five mine units were in production in 2014; five additional units were in restoration with Units 2 and 3 in stability monitoring; 4 and 5 in reverse osmosis treatment; and 6 in ion exchange treatment to remove residual uranium. Mine Unit 11 started production in November 2010.

1.2 ALARA Audit Requirements

License Condition 9.12 of Amendment No. 27 to RML No. SUA-1534 and License Condition 9.7 of the new License SUA-1534[1] requires an annual ALARA audit of the CBO mill radiation safety program consistent with the recommendations in Nuclear Regulation Commission Regulatory Guide 8.31 (NRC, 2002). In accordance with License Condition 9.7 and the guidance in Regulatory Guide 8.31, the records reviewed in the ALARA audit were as follows:

- Bioassay results
- Records of internal and external exposures
- Safety meeting minutes, attendance records, and training program records
- Routine inspection reports and Monthly RSO reports
- Radiological survey and monitoring data
- Environmental radiological effluent and monitoring data
- Radiation Work Permits (RWPs)
- Surveys required by RWPs
- Reports of overexposures submitted to the NRC
- Reviews of operating and monitoring procedures completed during the period
- Results of required leak tests on radioactive sources
- Instrument calibration records

In addition, the following topics were addressed:

- Trends in occupational radiation doses

[1] The license, issued on November 5, 2014, retains the same license number but is not a numbered amendment as it is considered a new license.

- Operation and maintenance of effluent control devices

1.3 Summary of General Site Activities in 2014

As noted in Section 1.1, five units are in restoration and five mine units are in production. The plant was fully operational for 2014 with a total yellowcake production of approximately 600,000 pounds. In November 2014, license SUA-1543 was renewed for the Crow Butte Operation. However, the provisions of the previous license, SUA-1543, Amendment 27, were in effect for most of 2014. The ALARA audit requirements for both versions are the same and are referenced to the Nuclear Regulatory Commission, Regulatory Guide 8.31 (NRC, 2002).

The Radiation Safety Officer (RSO), Rhonda Grantham, retired in September, 2014. Tami Dyer is the current RSO. Casey Yada is the Health Physics Technician (HPT). The Safety and Environment Review Panel (SERP) approved Mrs. Dyer's qualifications in accordance with the requirements of Reg Guide 8.31. The SERP also approved Mr. Yada's qualifications as the HPT. The Health Physics staff has been reduced by one full-time position. The SERP also approved Tate Hagman, Administrative Supervisor, as a qualified HPT to be used as necessary. Based on interviews with Mrs. Dyer and Mr. Yada, the staffing is adequate to meet most needs; however in some instances, additional help would be advisable.

Recommendation 1: One additional worker should be trained and qualified to perform routine health physics activities that do not require formal qualification as a HPT (e.g., data entry) in the event the HPT and RSO need assistance.

1.4 Occupational Dose Summary

Occupational radiation doses are discussed in detail in Section 2.1.2 and 2.1.3. The committed effective dose equivalent (CEDE) for each monitored worker is calculated quarterly based on average uranium concentration in airborne particulate material and the radon daughter concentration in each area the individual works and the time spent in the area. The total effective dose equivalent (TEDE) is calculated quarterly based on the deep dose equivalent measured by the worker's badge and the total CEDE for the three months of the quarter. The maximum occupational dose for 2014 was 0.437 rem for a dryer operator. The average TEDE for 2014 was 0.164 rem. This is similar to the average TEDE for 2013. The distribution of TEDEs for all workers is shown in Figure 1.

The distribution of annual TEDEs in 2014 indicates two distinct classes of worker doses with all annual doses less than the 0.5 rem per year that requires dose tracking under 10 CFR 20. Dose distribution data for previous years was not readily available to the auditors so no comparison was made to previous years.

The radiation safety data, including the dose records, are entered into Cameco's CAMRAD data base. The trends in average and maximum annual doses prepared by Cameco from the CAMRAD database are shown in Appendix A.

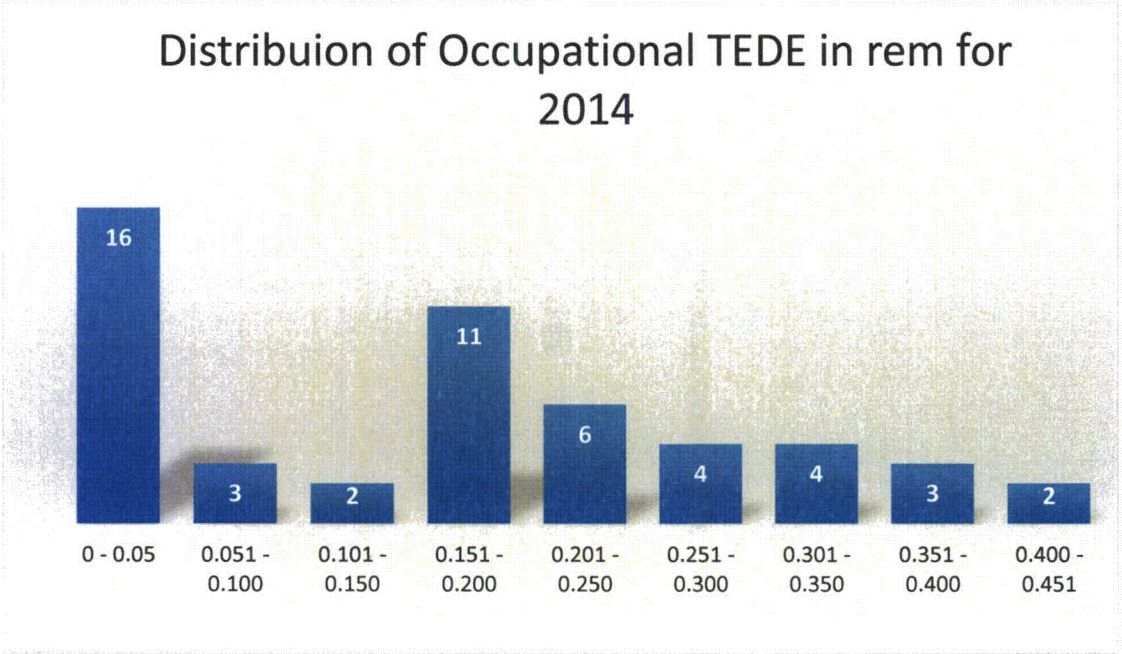

Figure 1. Distribution of occupational doses for 2014.

1.5 Public Dose Summary

The potential dose to members of the public is calculated based on the average measured concentrations of radionuclides in airborne particulate matter, radon concentration, and measured total gamma dose for the calendar year. The potential doses at all monitoring stations are calculated and reported in the Semi-Annual Radiological Effluent and Environmental Monitoring Report for the second half of the calendar year.

Monitoring Station AM-2 is located at the nearest residence. AM-6 is the background monitoring station. The net 2014 average uranium concentration at AM-2 was 8 E-17 µCi/mL. The dose from inhalation of uranium was calculated by multiplying the ratio of the average measured concentration to the 10 CFR 20 Appendix B, Table 2 effluent standard (9 E-14 µCi/mL) by 50 mrem/y. The estimated dose from inhalation of uranium was 0.04 mrem/y. The annual average measured concentrations of Ra-226 and Pb-210 at AM-2 were less than the measured concentrations at the background monitoring station. The net annual average radon concentration was 1 E-10 µCi/mL, equal to the effluent standard for Rn-222 in equilibrium with its decay products. The estimated dose from radon decay products was 50 mrem/y.[2] The net total gamma dose for the year 2014 was 2.6 mrem for a total effective dose equivalent (TEDE) of 52.6 mrem, which is below the 10 CFR 20.1301 dose limit for members of the public.

The method of calculating the public dose changed for 2014. In previous years, the measured radon concentration has been compared to the 10 CFR 20, Appendix B, Table 2 effluent limit for radon with no decay products present. Since the method of calculating dose has changed, the trend in the dose to the nearest resident is not presented in this ALARA Report.

[2] It is unlikely that the radon at AM-2 attributable to the CBO emissions is in equilibrium with its decay products, due to its short travel time from the central processing plant. Therefore, the calculated dose is an overestimate of the potential dose to a member of the public at that location.

2.0 ALARA AUDIT RESULTS

The 2014 ALARA Audit was conducted on February 24 – 27, 2015 at the Crow Butte In Situ Recovery facility in Crawford, Nebraska (CBO). The auditors were assisted by in obtaining information by Larry Teahon, SHEQ manager, Tami Dyer, Radiation Safety Officer and Casey Yada, Health Physics Technician.

Records reviewed by the auditors prior to or during the site visit are listed in Table 2.

Table 2. Records reviewed for the audit

Environmental Health and Safety Manual
Nuclear Regulatory Commission inspection reports
Previous audit reports
RSO and HPT training Records
Annual radiation worker training records
Visitor orientation records
Bioassay laboratory reports
Worker dosimetry reports
Radon decay product measurements
Air particulate measurement data
Routine inspection logs (daily walk through and weekly RSO inspection)
Monthly RSO reports
SERP records
Monthly Safety Meeting records
Quarterly RSO staff performance review
Survey instrument calibration records
SHEQ Monthly Reports
RWPs
Semi-annual environmental monitoring reports
Environmental gamma measurement data
Environment air particulate concentrations
Respirator program

Results of the ALARA Audit records review are discussed by sections as shown in Table 3.

2.1 Routine Operations

2.1.1 Bioassay Data

Routine bioassays are conducted quarterly for all CBO personnel with the potential for exposure to uranium and monthly for individuals working in the dryer facility and packaging yellowcake. The samples are submitted to Intermountain Laboratories in Sheridan, Wyoming for analysis. Intermountain Laboratories IML) operates under Radioactive Materials License No. 49-29405-01 which expires on 10/30/2020.

Table 3. Audit results by report section.

Report Section	Audit Records Discussed
2.1	Routine operations (Bioassay data, internal doses, external doses
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As summarized in Table 4, a total of over 200 samples were submitted to IML in 2014. They included routine monthly and quarterly samples, pre-employment and termination samples. In addition several samples were submitted in response to an incident in February, 2014 that could have resulted in exposure to a worker[3]. Each batch of samples was accompanied by two spiked samples and one blank. The spiked samples and blanks were prepared from synthetic urine prepared in the CBO laboratory and submitted as blind samples under the names of workers. The results of all spiked samples were within the quality control limits. The largest deviation between the actual spike concentration and laboratory result was less than 20 percent. All measured blank sample concentrations were below the reporting limit of 5 micrograms per liter (µg/L).

With one exception, all urine bioassay concentrations were less than the laboratory reporting limit, 5 µg/L The uranium concentration in one employee sample, collected in September 2014, was reported as 6.2 µg/L. The laboratory was contacted and reanalysis of the sample was requested. The results of the reanalysis were 6.67 µg/L, 5.79 µg/L, and 6.15 µg/L. The concentrations were below the level that requires investigation under NRC Regulatory Guide 8.22 (NRC, 2014). However the elevated concentration was investigated as an ALARA issue. The individual submitted a second urine sample. The concentration was less than 5 µg/L. This is considered a "best practice".

Best Practice 1: The investigation of the bioassay result that exceeded the laboratory reporting limit is a best practice. Regulatory Guide 8.22 (NRC, 2014) does not require investigation until the concentration exceeds 15 µg/L for a monthly bioassay schedule. The elevated bioassay was observed in a worker on the quarterly bioassay schedule so investigation at levels below 15

[3] Break in a PVC line as an operator was attempting to move a water hose.

µg/L is advisable since the intake retention function is significantly lower for a three month sampling interval.

Table 4. Results of urine bioassay samples submitted during 2014.

Date collected	No. samples	Spike 1	Spike 2	Uranium concentrations (µg/L)
1/2/14	1	17 (16.53)*	51.8 (49.59)	<5
1/24/14	2	16.9 (16.26)	50.6 (48.78)	<5
2/24/14	1	16.7 (16.67)	50.9 (50.0)	<5
2/24/14	2	16.0 (16.53)	48.8 (49.59)	<5
3/8-3/10/14	45	18.4 (16.13)	55.0 (48.39)	<5
3/26/14	1	17.9 (16.53)	52.9 (59.59)	<5
4/13/13	1	15.9 (16.26)	50.9 (48.78)	<5
5/2/14	1	18.1 (16.0)	53.7 (48.0)	<5
5/10/14	1	19.5 (16.39)	56.4 (49.18)	<5
5/18-19/14	6	18.4 (16.13)	50.8 (48.39)	<5
5/27/14	1	18.2 (16.81)	54.6 (50.42)	<5
6/9/14	48	17.1 (16.26)	50.5 (48.78)	<5
6/11-6/16/14	2	17.5 (16.53)	51.3 (49.59)	<5
7/6-7/8/14	3	17.8 (16.13)	52.4 (48.39)	<5
7/14/14	1	19.5 (16.39)	50.7 (52.1)	<5
9/3/14	1	17.6 (16.26)	59.8 (48.78)	<5
9/8/14	44	17.7 (16.7)	52.4 (50.0)	<5 6.2
9/17/14	1 (Resample)			<5
9/13-9/17	2	17.3 (16.39)	53.3 (49.18)	<5
10/10/14	2	16.6 (16.13)	50.7 (48.39)	<5
10/28/14	1	17.5 (16.26)	51.4 (48.78)	<5
11/15/14	1	17.9 (16.26)	53 (48.78)	<5
12/8/14	40	15.9 (16.13)	46.7 (48.39)	<5
12/18/14	5	17.3 (16.67)	53.6 (50.0)	<5

Recommendation 2: The RSO should document the review the bioassay laboratory reports as soon as they are received by signing and dating the report for the file.

Recommendation 3: When an exceedance of the laboratory reporting limit of 5 µg/L occurs and a re-sample is obtained, the laboratory should be asked to report the actual measured concentration and the uncertainty rather than " less than" 5 µg/L.

2.1.2 Internal Doses

The Committed Effective Dose Equivalent (CEDE) for workers is calculated based on the estimated intake of uranium (µCi) and exposure to radon decay products (WLM). The ratio of the calculated annual uranium intake to the Annual Limit of Intake (ALI) for soluble uranium is

multiplied by 5 rem to obtain the dose. The maximum and average doses to workers are reported in the Monthly Radiation Safety Report.

2.1.2.1 Radionuclide Concentrations in Airborne Particulate Matter

Uranium concentrations in air are measured in plant areas using area samplers with flow rates in the range of 40 to 50 L/m and breathing zone samplers with flow rates of approximately 5 L/m. The measured uranium concentrations are used in conjunction with the worker's time in the area to calculate the potential uranium inhalation intake. The concentration calculations were reviewed and found to be accurate. The monthly maximum and average uranium intakes are shown in Table 5. All calculated monthly intakes were less than 10% of the ALI, pro-rated over a 12 month period.

Table 5. Monthly and average uranium intake by workers for 2014.

Month	Maximum U Intake (µCi)	Average U Intake (µCi)
January	2.14E-3	5.93E-4
February	1.13E-3	5.25E-4
March	1.47E-3	5.37E-4
April	1.03E-3	3.91E-4
May	1.46E-3	5.21E-4
June	7.96E-4	3.13E-4
July	1.18E-3	6.17E-4
August	1.41E-3	5.28E-4
September	1.07E-3	4.06E-4
October	9.65E-4	3.34E-4
November	1.12E-3	5.73E-4
December	1.13E-3	5.73E-4

2.1.2.2 Radon and Radon Decay Product Concentrations

Radon concentrations are measured in approximately 30 areas within the facility. The detectors are exchanged quarterly. The measured concentrations for the first half of 2014 ranged from 0.2 pCi/L to 76.9 pCi/L (inside WH #9). All measurements with the exception of WH#9 were less than 6 pCi/L. All but two of the measured radon concentrations were less than the EPA guideline for residential structures.

Radon decay product concentrations are measured monthly in 12 locations in the plant using the Modified Kusnetz method. The calculations in the spread sheet were checked and found to be accurate. The calculated Working Level (WL) is multiplied by the number of hours the worker was exposed, divided by 170 working hours per month to obtain the worker exposure in Working Level Months (WLM). The total number of WLM for the month is multiplied by a dose factor of 1.25 rem per WLM. The maximum and average doses due to radon decay product exposure are reported in the Monthly Radiation Safety Report and are given in Table 6.

All radon decay product exposures were less than 10% of the prorated monthly exposure limit 0.33 WLM based on 4 WLM per year.

Table 6. Worker doses from radon decay product exposures during 2014.

Month	Maximum WLM	Average WLM
January	0.009	0.006
February	0.011	0.007
March	0.011	0.007
April	0.012	0.007
May	0.017	0.008
June	0.015	0.008
July	0.026	0.014
August	0.006	0.003
0.014	0.0130	0.0063
October	0.0009	0.0006
November	0.0108	0.0066
December	0.0226	0.0131

2.1.3 External Doses

Occupational direct gamma and beta radiation doses are measured using Optically Stimulated Luminescent (OSL) dosimeters supplied by Landauer, Inc. The dosimeters measure deep dose, equivalent, shallow (skin) dose and dose to the lens of the eye. The dosimeters are exchanged quarterly. When not in use, dosimeters are stored on a badge board in the lunchroom. Workers pick up their dosimeters at the start of the shift and return them to the badge board at the end of the shift. The control badge is stored on the badge board. The vendor subtracts the control badge dose from the worker badge dose to obtain the reported dose to the worker.

The dose rate at the badge board is approximately twice the background dose rate measured at a different location in the plant. Therefore, the control badge overestimates the background, thus the worker doses are underestimated when the control badge dose is subtracted. Based on the average quarterly control badge dose rate (71 mrem/quarter) and the measured background dose rate (31 mrem/quarter) the estimated "missed" worker dose is approximately 9 mrem/quarter or 37 mrem/year. The calculations to support this estimate are included in Appendix B.

Recommendation 4: Move the badge board to a convenient background location to mitigate the problem of underestimation of worker doses.

2.1.4 Total Effective Dose Equivalent (TEDE)

The TEDE for each worker is calculated by adding the dose from inhalation of radon decay products and uranium in airborne dust to the deep dose equivalent (DDE) measured using the worker's OSL badge. The Annual TEDE for individual workers is shown in Figure 2. The annual average 2014 CEDE from inhalation of Rn decay products was 0.089 rem; the CEDE from inhalation of uranium was 0.024 rem; the average DDE from direct radiation was 0.052 for an average TEDE of 0.165 rem or 3.3 percent of the annual occupational dose limit. The maximum annual TEDE was 0.437 rem or 8.7 percent of the annual dose limit. All of the worker

doses were less than 10 percent of the annual dose limit, the level that requires dose monitoring under 10 CFR 20.1502.

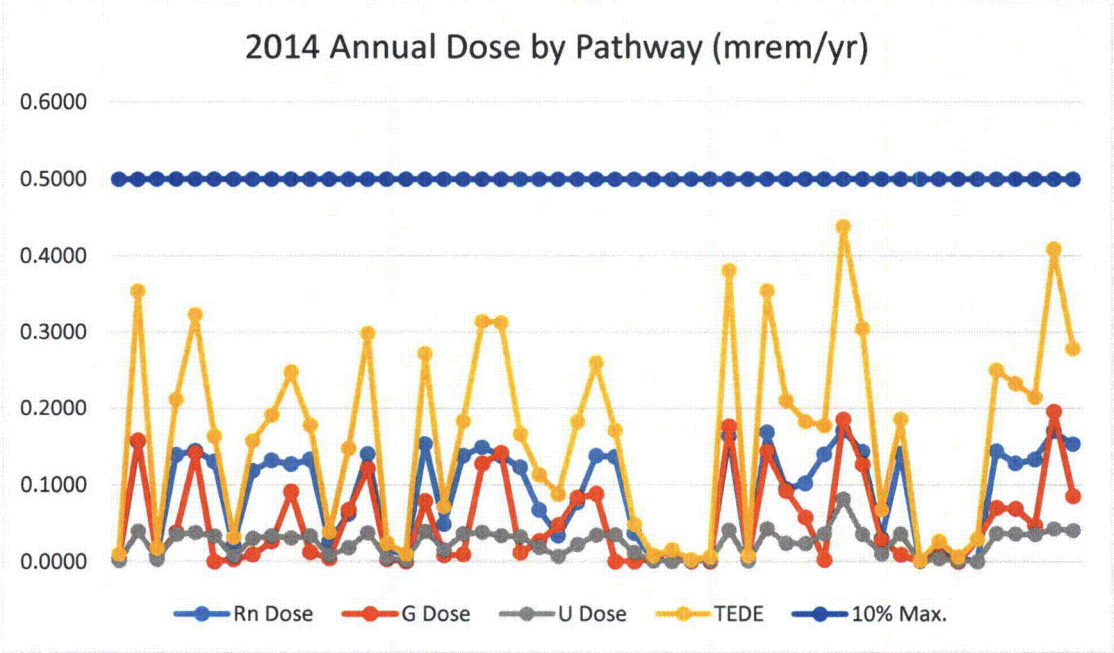

Figure 2. Worker doses by pathway in 2014.

Regulatory Guide 8.31 specifies that the ALARA audit should discuss "trends in personnel exposures for identifiable categories of workers and types of operational activities." The Cameco dose records identify the type of work performed by the monitored individual. Based on the dose records the workers were tentatively classified by the type of work. The auditor merged several categories to summarize the exposures by type of worker. The results are given in Table 7.

Table 7. Total Effective Dose Equivalent (TEDE) by Worker Classification for 2014.

Worker Class	# of workers	Total Effective Dose Equivalent (mrem/y)		
		Min.	Max.	Ave.
Administrative	8	0.002	0.248	0.110
Lead	5	0.031	0.380	0.262
Maintenance	3	0.008	0.298	0.189
Miscellaneous	10	0.006	0.183	0.082
Plant	12	0.026	0.437	0.233
Pulling Unit	6	0.048	0.272	0.159
Restoration	3	0.018	0.312	0.211
Wellfield	4	0.006	0.182	0.101

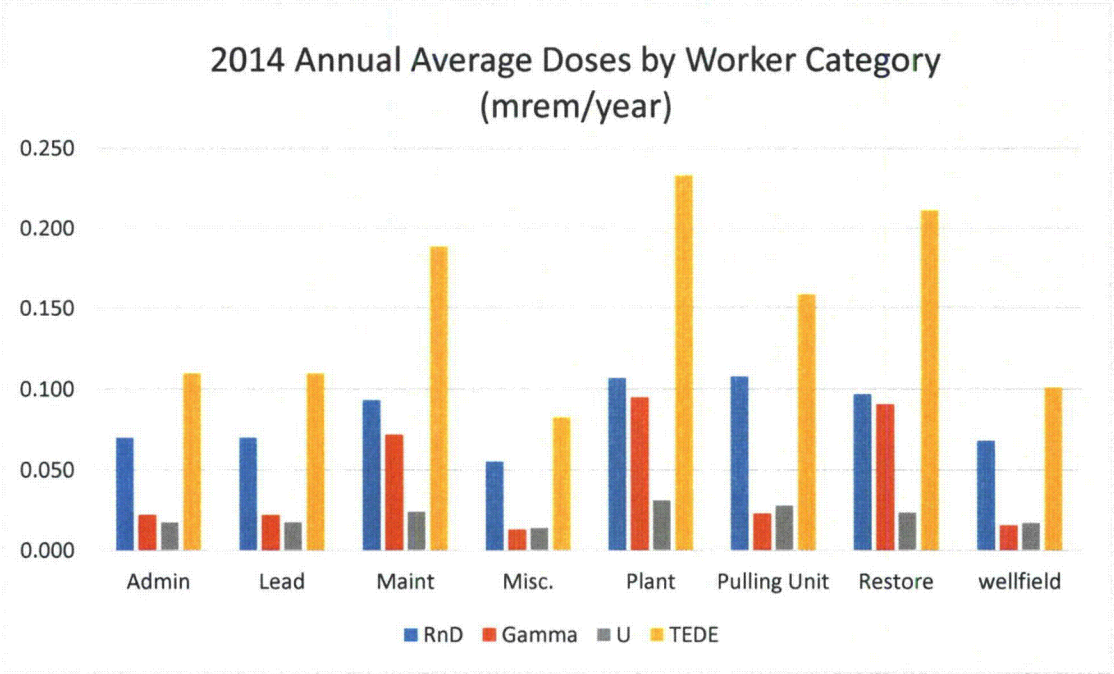

Figure 3. Average annual worker doses by category.

Worker doses for previous years were not analyzed by category so no trends could be established.

Recommendation 5: Consider adding the capacity to analyze annual average doses for specific categories of workers to the CAMRAD data base.

The annual dose is reported to each employee in a Cameco-specific format that includes the same information as is provided on the NRC Form 5 Occupational Dose Record for a Monitoring Period with the exception that the Cameco form does not report the eye or shallow equivalent doses. The information is summarized in tables and graphics. The lack of eye and shallow dose data is of no practical consequence for the work performed at this site. A review of the OSL badge reports demonstrated that the eye and shallow doses were not significantly different from the deep dose equivalents that are reported on the Cameco form.

Recommendation 6: When annual dose report form is revised, change the title from "Annual Employee Exposure Summary" to the correct terminology "Annual Employee Dose Summary" The RSO should sign and date the annual dose reports.

2.1.5 Personal Contamination Surveys

The personal scanning system at the Crow Butte facility is cumbersome and time consuming. The auditors have several recommendations for improvements to the system.

Recommendation 7: The laboratory is in an unrestricted area. However, laboratory workers currently are required to scan out at the south plant scanning station ("bunker") since there is a potential for contact with radioactive materials in the lab. That process requires the workers to go through the plant to access the scanning station. That process is not ALARA since the

workers are unnecessarily exposed to higher levels of radon and direct gamma radiation in the plant. A scanning station for laboratory use only should be set up at the doorway to the lab so workers may scan out without going through the plant.

Recommendation 8: Because the shower rooms are situated such that the single entrance/exit is to a restricted zone, the auditors recommend that the entrance atrium from the exit to the scanning area be treated and surveyed as if it were an unrestricted area, i.e., in the same manner as the lunchroom, recognizing that it is still within the restricted area.

Recommendation 9: Create and install a cradle for the scanning probe in the scanning booth so that one hand may be scanned prior to touching the probe to prevent possible contamination of the detector.

Recommendation 10: The current practice for scanning clothing is to take a static measurement on one section of the clothing. The auditors recommend scanning by moving the detectors at a rate of no more than one inch per second over the surface of the clothing. A static measurement should then be taken over the area that showed the highest count rate. The current method risks missing a portion of the clothing that might be contaminated. The current static measurement should be continued for hands and boots.

Recommendation 11: Explore other options for adequate scanning. The current method is time consuming and results in time wasted while waiting in line to scan out during periods of high usage.

2.2 Safety Meeting Minutes, Attendance Records, and Training Program Records

2.2.1 Safety Meeting Records

"All-hands" safety meetings are held monthly. Records of the meetings were reviewed. The safety meeting records are complete and indicate a variety of topics covered. The dates and topics discussed at the meetings are given in Table 8.

2.2.2 Radiation Worker Training

Introductory radiation safety training is conducted for all new employees according to materials reviewed by the auditors. Rad worker refresher training is conducted in April every year. A quiz is administered at the end of training. A sample of completed tests was reviewed by the auditors. As part of the refresher training, the RSO conducts a "Rad Bowl" competition, to test the workers knowledge. The training program is adequate and meets the requirements of Regulatory Guide 8.31.

Table 8. Safety meeting date and topics during 2014.

Date	Subjects	Attendees
1/15/14	ALARA, General safety	42
2/26/14	Annual Dose Reports distributed and discussed	38
3/26/14	Safety, relicensing	46
	Annual Radiation Safety Training	
5/14/14	Safety	36
6/25/14	Safety, biohazards	29
7/23/14	Tornado Safety, Safety, Health and Environment Quality (SHEQ)	34
8/27/14	School safety, new drillers, PPE	37
9/24/14	Snow, positive bioassay sample, weather issues	32
10/3/14	Safety, winter weather, slips, trips, falls, radiation safety, training new workers	28
11/12/14	Equipment	32
12/18/14	New license conditions, pollution prevention	

2.2.3 Planned Task Observation

The RSO conducts a "Planned Task Observation" quarterly to evaluate the performance of the HPTs. Table 9 lists the topics covered by the evaluations in 2014.

Table 9. Topics covered in Planned Task Observation evaluations in 2014.

Date	Evaluator	Task Observed
2/1//14	Tami Dyer	Equipment and materials release survey
3/10/14	Casey Yada	Alpha contamination survey performance
6/10/14	Tami Dyer	Respirator fit testing
9/11/14	Casey Yada	Calibration of environmental pumps
11/17/14	Casey Yada	Unrestricted alpha/beta survey
12/18/14	Casey Yada	Outbuilding spot check

2.3 Inspection Reports

2.3.1 Routine Inspections

Daily walk-through inspections are conducted in the plant. Each walk-through inspection log covers a full week. The individual performing the walk-through signs the form. A sample of the walk-through checklist was reviewed. No issues were noted.

The RSO or her qualified designee performs a weekly inspection of the site accompanied by the Mine Manager or Plant Forman. Representative copies of the form were reviewed. The inspection is documented in a memo to the Mine Manager and a monthly inspection form. The inspections are compliant with Regulatory Guide 8.31.

2.3.2 NRC Inspections

The annual NRC inspection took place June 3 – 5, 2014. The inspection concluded that "the licensee was conducting operations in accordance with regulatory and license requirements." There were no items of non-compliance identified. A violation from the 2013 inspection in regard to an exposure rate in an area accessible to the public exceeded 2 mrem/hr was closed out. The situation was mitigated at the time of the inspection by fencing off the area. Routine gamma exposure rate surveys around the facility were instituted to ensure that all areas that are accessible to the public have exposure rates less than 2 mrem/hour.

The NRC inspectors reviewed SERP 13-05 that approved the qualifications of the HPT. The inspectors determined that the qualifications of that individual did not meet the education and experience requirements in Regulatory guide 8.31. The HPT has received further training and has been re-qualified through SERP 14-10.

2.3.3 ALARA Audit

The 2013 ALARA Audit was conducted by R and D Enterprises in January, 2014. The recommendations from that audit are discussed in Section 2.10.

2.4 Radiological Survey and Monitoring Data

2.4.1 Monthly gamma exposure rate surveys

Monthly gamma exposure surveys are conducted outside the CPP, RO facility and the Well Houses. The maximum exposure rates at various locations inside and outside the plant are recorded and compared with the previous month's data. All Well Houses with exposure rates above 5 mrem/hr are posted as Radiation Areas. No areas outside the Well Houses had exposure rates exceeding 2 mrem/hr.

The maximum exposure rates measured outside the CPP and the RP facility are given in Table 10.

The Solid Waste Area is also surveyed monthly. The exposure rates are in the range of background.

2.4.2 Contamination Surveys

Routine alpha and beta removable contamination surveys are performed monthly in the restricted and unrestricted areas. Representative records were reviewed. No issues were identified.

A representative sample of release surveys for equipment was reviewed. Total and removable contamination levels were evaluated. No issues were identified.

Table 10. Maximum measured outside gamma dose rate (mrem/hr)

	Maximum measured dose rate (mrem/hr)	
Month	**Outside CPP**	**Outside RO plant**
January	1.0	1.2
February	1	1.2
March	1	1.3
April	1	1
May	1	1
June	1	1.1
July	1	1
August	1	1.1
September	0.8	0.2
October	0.8	0.3
November	0.8	0.3
December	0.6	0.3

2.5 Radiation Work Permits (RWPs)

A total of 17 Radiation Work Permits (RWPs) were issued in 2014. RWPs are issued for non-routine activities that involve the potential for significant exposure to radioactive materials and for which there are no standard operating procedures. The 2014 RWPs are listed in Table 11. RWPs describe the activity, personnel involved, radiological data and protective equipment required. The Health Physics Manual requires individuals who will perform the task to read and sign the RWP. The participants actually initial the section listing the personnel to be involved in the task. Monitoring data are attached to the RWP. The RWPs were reviewed for completeness. No issues were found.

2.6 Safety and Environmental Review Panel (SERP)

The SERP is tasked with approving changes in the facility or procedures as described in the license application and conduct tests or experiments not described in the license application as long as conditions specified in License Condition 9.4 (Amendment 27) are met. License Condition 9.4D defines the purpose and makeup of the SERP. The SERP approved ten actions in 2014 briefly described in Table 12.

SERP actions in regard to radiation safety personnel were supported by the information in the SERP document. The information in the SERP evaluations justified the actions. The auditors did not evaluate the SERP actions with regard to additional monitoring wells.

Table 11. Radiation Work Permits issued during 2014.

RWP #	Description of work	Date Initiated	Date Terminated	Record complete?
14-1	Replace suction pipe on DDW#1	1/6	?	RWP signed off but no termination date
14-2	Modify CIP Unit	1/7	1/22	Yes
14-3	Clean and change filter media	1/17	1/22	Yes
14-4	Replace steam line valve #1 dryer	2/12	1/20	Yes
14-5	Inspect interior walls of resin trailer	2/19	2/24	Yes
14-6	Clean RO Unit #1	2/24	2/28	Yes
14-7	Inspect and repair raw water tank	3/10	3/17	Yes
14-8	Open tank and clean sludge	3/10	3/17	Yes
14-9	Change yellowcake dryer gasket	3/12	3/17	Yes
14-10	Install demister in W vent line	3/26	4/2	Yes
14-11	Clean D7 witches hats on D7 injection line	4/9	4/14	Yes
14-12	Clean RO units – SOP to be finalized	4/28	1/7/15	Yes
14-13	Install column blower demister in E column train	4/29	5/2	Yes
14-14	Change bags in YC dryer baghouse	5/12	8/27	Yes
14-15	Clean, inspect and repair Down Flow-Column 3	7/28	1/7/15	Yes but not terminated until 2015
14-16	Replace manifold screens in IX-6	12/10	12/15	Yes
14-17	Grind deepwell #1 pump base off and bolt back down	12/16	12/17	Yes

2.7 Environmental Radiological Effluent and Surveillance Data

Airborne radionuclide concentrations and direct gamma radiation dose rates are measured quarterly at three air monitoring stations around the perimeter of the site, three at residences and one background location. Radon concentrations are measured semi-annually at the same locations. The measured concentrations and the gamma exposure rate are used to calculate the potential dose to a member of the public.

Table 12. SERP actions taken during 2014.

SERP Evaluation Number	Date	Action Taken
SERP 14-1	1/27/14	Approved WH35A and additional monitor wells
SERP 14-2	4/2/14	Approved WH47A/65 partial start-up
SERP 14-3	4/22/14	Approved additional wells started in WH47A/65
SERP 14-4	4/22/14	Approved replacement of CM 11-13 with CM 11-13A – Approved Tate Hagman as interim RSO (as necessary)
SERP 14-5	6/10/14	Approved additional wells started in WH 47A/65
SERP 14-6	7/30/14	Approved RSO qualifications (Tami Dyer)
SERP 14-7	7/30/14	Approved HPT qualifications (Tate Hagman)
SERP 14-8	7/30/14	Approved organizational change
SERP 14-9	8/6/14	Approve additional wells started in WH 47A/65
SERP 14-10	12/19/14	Approved HPT qualifications for Casey Yada with additional training obtained in 2014

2.7.1 Radon Gas

Radon gas concentrations is measured using the Landauer, Inc. Radtrak alpha track detector. The detectors are exchanged quarterly with a minimum detectable concentration of 2E-10 µCi/mL (0.2 pCi/L). In 2014, three detectors were deployed at each monitoring location to assess reproducibility. The annual average radon concentrations for 2012, 2013, and 2014 are given in Table 13.

Annual average radon concentrations were lower in 2014 than in the previous two years. Beginning in 2014 Landauer adjusted their procedure for handing the detectors prior to deployment. Previously, the detector material had been stored for a period up to a year or more prior to deployment in the field and some of the packaging leaked prior to deployment resulting in spuriously high radon measurements. Duplicate measurements from 2012 and 2013 demonstrate the errors in the measurements. Current procedures have resulted in more stable and credible radon concentration measurements. Triplicate measurements for 2014 indicate reasonable consistency. Comparisons between 2014 radon concentrations and concentrations measured the previous years are not valid.

2.7.2 Radionuclides in Airborne Particulate Matter

Radionuclide concentrations in airborne particulate matter are measured at the same locations as the radon concentrations (Table 14). Particulates are collected on filters that are exchanged quarterly. The flow rate is approximately 50 liters per minute (L/m). The filters are analyzed for Uranium, Ra-226, Pb-210 and Th-230. (The measured Th-230 concentrations are not included in the annual dose to the public and are not listed in Table 14.)

Table 13. Annual average environmental radon concentration in air.

Station	2012 (uCi/mL)	2013 (uCi/mL)	2014 (uCi/mL)
AM-1 (residence)	3E-10	7E-10	3E-10
AM-2 (nearest downwind resident)	6E-10	1.4E-9	4E-10
AM-3 (permit area boundary)	4E-10	1.6E-9	3E-10
AM-4 (permit area boundary)	4E-10	6E-10	3E-10
AM-5 (residence)	8E-10	7E-10	4E-10
AM-6 (background)	6E-10	6E-10	3E-10
AM-8 (site boundary)	4E-10	2.0E-9	3E-10
Values in red print are suspect due to vendor measurement difficulties.			

Table 14. Annual average radionuclide concentrations in airborne particulate matter.

Year	Annual Average U-nat Conc. (µCi/mL)			Annual Average Ra-226 Conc. (µCi/mL)			Annual Average Pb-210 Conc. (µCi/mL)		
Location	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**
Effluent Limit	*9E-14*			*9E-13*			*6E-13*		
AM-1	2E-16	1E-16	1E-16	1E-16	1E-16	1E-16	2E-14	2E-14	2E-14
AM-2	3E-16	2E-16	2E-16	1E-16	1E-16	1E-16	2E-14	1E-14	2E-14
AM-3	2E-16	1E-16	1E-16	1E-16	1E-16	1E-16	3E-14	2E-14	1E-14
AM-4	2E-16	1E-16	1E-16	1E-16	1E-16	1E-16	2E-14	2E-14	2E-14
AM-5	2E-16	1E-16	2E-16	1E-16	1E-16	2E-16	2E-14	2E-14	2E-14
AM-6	2E-16	1E-16	1E-16	1E-16	1E-16	1E-16	2E-14	2E-14	2E-14
AM-8	2E-16	1E-16	1E-16	1E-16	1E-16	1E-16	2E-14	2E-14	2E-14

The radionuclide concentrations in airborne particulate matter are essentially the same for all three years and for all seven locations. There are no observable trends.

2.7.3 Direct Gamma Radiation

Direct gamma radiation doses at the seven air monitoring stations are measured using Landauer, Inc. dosimeters. The dosimeters are exchanged quarterly. The total annual gamma doses are given in Table 15.

Table 15. Annual measured gamma dose (mrem/yr), 2012 - 2014

	Annual Dose (mrem/y)		
Year/Station	**2012**	**2013**	**2014**
AM-1	29.6	31.0	29.0
AM-2	36.9	30.7	37.7
AM-3	34.3	39.9	38.0
AM-4	25.0	27.0	30.0
AM-5	36.4	34.4	38.1
AM-6	36.4	28.2	35.1
AM-8	44.8	47.0	43.2

Annual gamma doses for 2014 are consistent with the two previous years. There are no observable trends.

Recommendation 12: Radionuclide concentrations in air and direct gamma radiation dose rates are consistent with background. Environmental monitoring data in graphic format could be posted in the facility to demonstrate to employees and visitors that the Crow Butte facility meets all applicable environmental standards.

2.8 Instrument Calibration Records

Instrument calibration records were reviewed. The instruments and sources are listed in a table with calibration dates. Most of the radiation detection instruments are sent to the manufacturer (Ludlum Measurements) for calibration. The auditors checked the calibration dates on the instruments in service and determined that all are in current calibration. There are several instruments in the instrument lab that are not in use and are not in calibration. They are bagged and taken out of service. The instrument calibration records are contained in notebooks. The 2014 calibration notebook contained the calibration records without apparent organization making it difficult to check specific instruments. The 2015 calibration notebook is arranged by instrument serial number. The calibration list was checked against the records in the 2015 notebook.

Best Practice 2: The 2015 calibration records notebook is arranged in a way that facilitates verification of calibration of specific instruments. This is a significant improvement over the previous record keeping.

Recommendation 13: Label instruments that are out of calibration as "Not in use" or "Out of Service" to make it clear that the instruments may not be used for surveys.

Proper operation of the instruments used for personal scanning at the south plant location ("bunker") and the RO facility is verified weekly. The verification for the south plant instrument includes battery check and instrument alpha and beta efficiency checks as well as calculation of the maximum allowable alpha and beta counts for a 0.5 minute count time and the minimum detectable activity in disintegrations per minute per 100 cm^2. The spreadsheet calculations were checked and found to be accurate. The RO facility instruments are set to alarm at a specific count rate. The correction factor for the efficiency includes both the instrument efficiency and a factor to take into account the area of the detector. The spreadsheet calculations were checked and found to be accurate.

Plateau determinations and reliability factor checks are performed after calibration or repair or if the instrument response is questionable. The reliability factor calculation was checked and found to be accurate.

2.9 Source Leak Tests

The Crow Butte facility has no radioactive sources that require leak testing. The only sources on site are exempt instrument check sources.

2.10 Review of Radiation Protection Records

Radiation protection records were reviewed.

Best Practice 3: The records were readily available, generally well written, and in good order facilitating the audit and other uses of the information.

2.10.1 Respiratory Protection

The Respiratory Protection Program was reviewed. Full face piece air purifying respirators are used in situations where respiratory protection is required. When the dryer is operating, the dryer room is designated as an Airborne Radioactivity Area. Respiratory protection is required. The Respiratory Protection Program includes evaluation of medical fitness for respirator use, fit testing and training. Cameco uses Legends Butte Health Services in Crawford, Nebraska as the medical provider. Respirator training is included in the annual rad worker training.

Best Practice: Respirator storage conditions and maintenance are very good. There is a centralized respirator cleaning and storage facility with a clear assignment sheet and checkout system for the respirators.

2.10.2 Visitor Records

Visitors to the Cameco Crow Butte facility are not badged or issued personal dosimeters. Visitors are escorted when entering the Restricted Areas of the site. Passes are issued to site visitors. If the visitor enters the restricted area, the escort takes exposure rate measurements during the visit. Doses are estimated based on the measured exposure rates and recorded on the visitor pass.

Contractors and other individuals who may be on the site for an extended period of time must receive documented Hazard Recognition and Safety Orientation. The training, that includes radiation hazards, must be renewed annually and allows the individual unescorted access to specific work areas on the site. Contract workers who will enter the restricted area receive additional training from the RSO or HPT. Visitor records were not reviewed during this audit.

2.10.3 Equipment Release Surveys

Equipment and materials to be released for unrestricted use are surveyed for total contamination and wipe tested for removable contamination. Total contamination surveys for alpha and beta radiation are performed using a Ludlum Model 43-93 alpha/beta probe. Beta surveys were initiated in November 2014. The action limit is 750 d/m per 100 cm^2. The Reg. Guide 8.30 release criterion for uranium and its decay products is 1000 d/m alpha per 100 cm^2 and 5000 d/m per 100 cm^2 total (fixed plus removable) alpha. The release criteria for beta

radiation is the same. A representative release survey packet was reviewed and found to be compliant with the Reg Guide 8.30 requirements.

Note: There is an unexplained factor of 150/100 in the alpha and beta efficiency calculation. When the auditor queried the HPT, he had an immediate answer indicating that he has a good understanding of the calculation. (The efficiency is determined based on the total activity of a 150 cm^2 uranium source.)

2.10.4 Annual Review of Operating Procedures

The operating procedures are reviewed annually by the RSO. The review is documented on a log sheet with the date the procedure was reviewed and the initials of the reviewer. The RSO reviewed all of the operating procedures in 2014.

2.11 Unusual Events

Unusual events are documented in the SHEQ monthly reports along with the monthly average and maximum worker uranium intakes in µCi, radon decay product exposures in WLM, bioassay results and radiation work permits issued. "Unusual events" noted in the monthly reports are described in Table 16.

As noted previously, the SHEQ monthly reports are informative. They clearly describe unusual events and the actions taken to mitigate the consequences. The unusual events described in Table 16 were addressed appropriately in order to maintain radiation doses ALARA.

2.12 Review of 2013 ALARA Audit Recommendations

The 2013 ALARA Audit Report included several recommendations:

1. Improve electronic data entry and upload routines for the Cameco CAMRAD data base.

The CAMRAD data base is being revised to improve its usefulness. The revised version is expected to be operational in the fall of 2014.

2. Improve development of a corporate-wide electronic data storage system.

Electronic data storage systems would improve the accessibility of data and reduce the potential for transcription errors. This recommendation is open.

3. Reduce radiation areas within the plant. Process and engineering improvements could further reduce external gamma radiation occupational exposures.

   CBO is taking steps to reduce radiation areas within the plant and to reduce radon concentrations in work areas. However additional improvement could be made in this regard. This is an open recommendation.

Table 16. Unusual radiological events during 2014.

Month	Event Noted	Actions taken
January	Dried yellowcake observed on the wall of the belt filter room.	Yellowcake was cleaned.
February	Plant accident involving potential exposure to yellowcake.	Bioassay sample collected. Result was less than the reporting limit.
March	None	
April	None	
May	During daily inspection, dry yellowcake identified around air sampling pump in the belt filter room.	Method for cleaning residual yellowcake from the pump hose was instituted to prevent re-occurrence.
June	Overflowing sump and make-up water tank in the pond water treatment plant room due to faulty valve.	Sump pumped out and floor washed down. Procedure changed to manual fill valve to prevent re-occurrence.
July	Elevated gamma dose rate on the filter canisters for Deep Disposal Well #2 observed during monthly gamma survey.	Filters changed and the dose rate was reduced. Frequency of filter change increased.
August	Elevated radon decay product concentration identified in WH #61.	Respiratory protection required during well-house degassing until additional data collected.
September	None	Data collected on radon decay product concentrations during well house degassing. Vent on the water truck moved so it vents above the tank instead of underneath the tank. Radon levels decreased.
October	None	
November	None	
December	None	

3.0 SUMMARY OF 2014 AUDIT FINDINGS AND RECOMMENDATIONS

3.1 Findings

There were no findings from this audit

3.2 Recommendations

Recommendation 1: One additional worker should be trained and qualified to perform routine health physics activities that do not require formal qualification as a HPT (e.g., data entry) in the event the HPT and RSO need assistance.

Recommendation 2: The RSO should document the review the bioassay laboratory reports as soon as they are received by signing and dating the report for the file.

Recommendation 3: When an exceedance of the laboratory reporting limit of 5 µg/L occurs and a re-sample is obtained, the laboratory should be asked to report the actual measured concentration and the uncertainty rather than " less than" 5 µg/L.

Recommendation 4: Move the badge board to a convenient background location to mitigate the problem of underestimation of worker doses.

Recommendation 5: Consider adding the capacity to analyze annual average doses for specific categories of workers to the CAMRAD data base.

Recommendation 6: When annual dose report form is revised change the title from "Annual Employee Exposure Summary" to the correct terminology "Annual Employee Dose Summary" The RSO should sign and date the annual dose reports.

Recommendation 7: The laboratory is in an unrestricted area. However, laboratory workers currently are required to scan out at the south plant scanning station ("bunker") since there is a potential for contact with radioactive materials in the lab. That process requires the workers to go through the plant to access the scanning station. That process is not ALARA since the workers are unnecessarily exposed to higher levels of radon and direct gamma radiation in the plant. A scanning station for laboratory use only should be set up at the doorway to the lab so workers may scan out without going through the plant.

Recommendation 8: Because the shower rooms are situated such that the single entrance/exit is to a restricted zone, the auditors recommend that the entrance atrium from the exit to the scanning area be treated and surveyed as if it were an unrestricted area, i.e., in the same manner as the lunchroom, recognizing that it is still within the restricted area.

Recommendation 9: Create and install a cradle for the scanning probe in the scanning booth so that one hand may be scanned prior to touching the probe to prevent possible contamination of the detector.

Recommendation 10: The current practice for scanning clothing is to take a static measurement on one section of the clothing. The auditors recommend scanning by moving the detectors at a rate of no more than one inch per second over the surface of the clothing. A static measurement should then be taken over the area that showed the highest count rate. The

current method risks missing a portion of the clothing that might be contaminated. The current static measurement should be continued for hands and boots.

Recommendation 11: Explore other options for adequate scanning. The current method is time consuming and results in time wasted while waiting in line to scan out during periods of high usage.

Recommendation 12: Radionuclide concentrations in air and direct gamma radiation dose rates are consistent with background. Environmental monitoring data in graphic format could be posted in the facility to demonstrate to employees and visitors that the Crow Butte facility meets all applicable environmental standards.

Recommendation 13: Label instruments that are out of calibration as "Not in use" or "Out of Service" to make it clear that the instruments may not be used for surveys.

3.3 Best Practices

Best Practice 1: The investigation of the bioassay result that exceeded the laboratory reporting limit is a best practice. Regulatory Guide 8.22 (NRC, 2014) does not require investigation until the concentration exceeds 15 µg/L for a monthly bioassay schedule. The elevated bioassay was observed in a worker on the quarterly bioassay schedule so investigation at levels below 15 µg/L is advisable since the intake retention function is significantly lower for a three month sampling interval.

Best Practice 2: The 2015 calibration records notebook is arranged in a way that facilitates verification of calibration of specific instruments. This is a significant improvement over the previous record keeping.

Best Practice 3: The records were readily available, generally well written, and in good order facilitating the audit and other uses of the information.

4.0 REFERENCES

[NRC] Nuclear Regulatory Commission. 1993. Guidelines for Decontamination of Facilities and equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source or Special Nuclear Material. April.

[NRC] Nuclear Regulatory Commission. 2002. Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Recovery Facilities Will Be As Low As Reasonably Achievable. Regulatory Guide 8.31. Revision 1. May.

[NRC] Nuclear Regulatory Commission. 2014. Bioassay at Uranium Mills. Regulatory Guide 8.22. Revision 2. May.

APPENDIX A

Occupational Dose Trends

Trends in occupational radiation doses for the past 21 years are shown in the attached Figures from the CAMRAD data base. The average and maximum annual doses from exposure to radon decay products are given in Figure A-1. The average and maximum annual doses from exposure to uranium in airborne particulate matter are given in Figure A-2. The average and maximum annual doses from direct radiation are given in Figure A-3. The average and maximum Total Effective Dose Equivalent (TEDE) values are shown in Figure A-4. The combined doses (person-rem) per ton of U3O8 produced are given in Figures A-5 and A-6. The combined dose for 2014 was calculated manually as this metric was not available at the time of the ALARA audit. The combined dose per ton of U3O8 produced in 2014 was 0.028 rem (280 mrem/ton, 0.28 mSv/ton).

The average annual doses from the three pathways have remained relatively consistent. Maximum doses appear to have deceased since the years 2009 through 2011 reflecting attention to ALARA issues. The combined dose per ton of U3O8 has decreased since 2011.

Note: There may be some slight discrepancies between the values represented in the figures and the values given in the text of the ALARA audit report, primarily due to rounding issues.

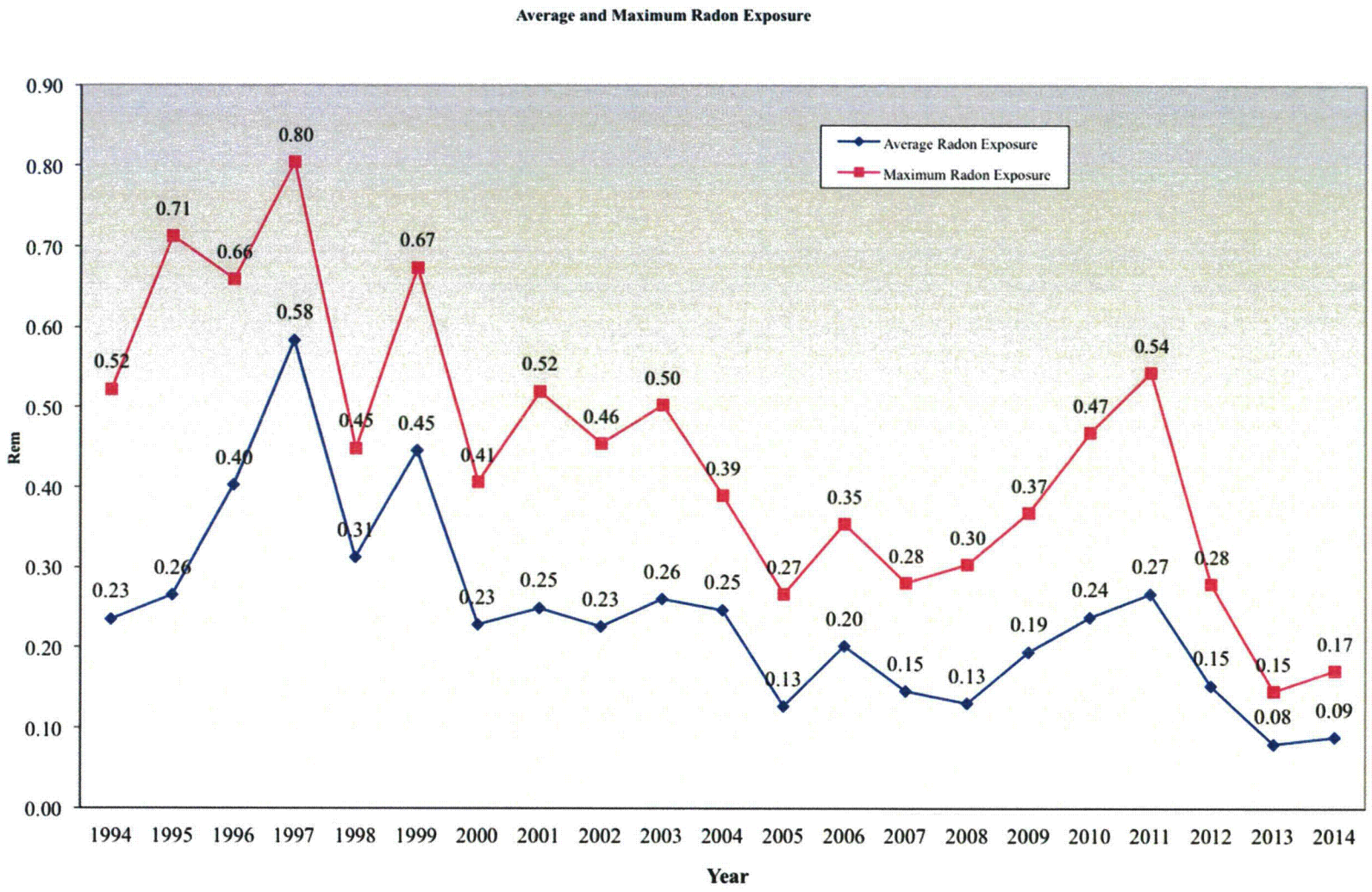

Figure A-1. Average and Maximum Radon Exposure Analysis.

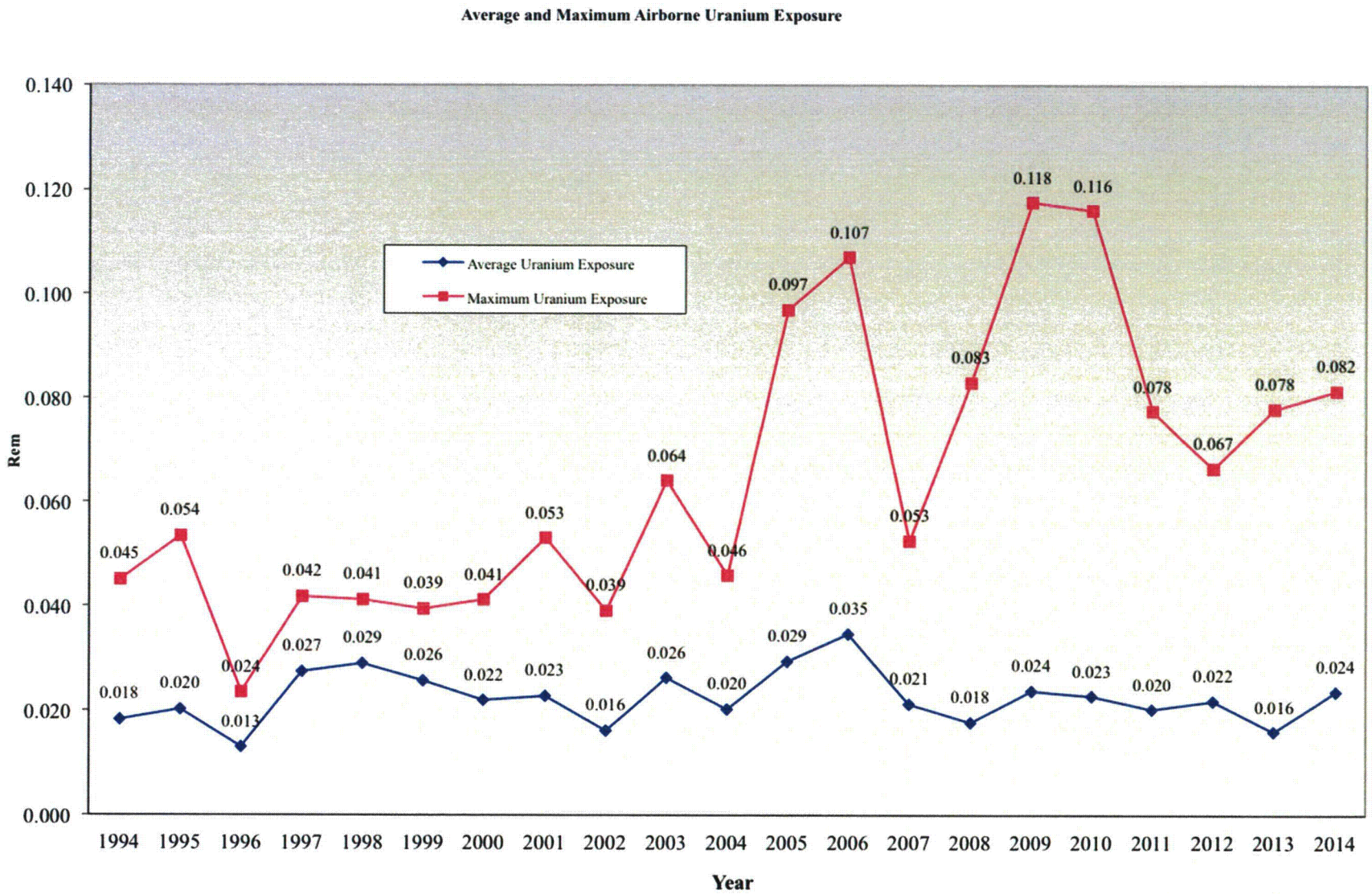

Figure A-2. Average and Maximum Airborne Uranium Exposure Analysis.

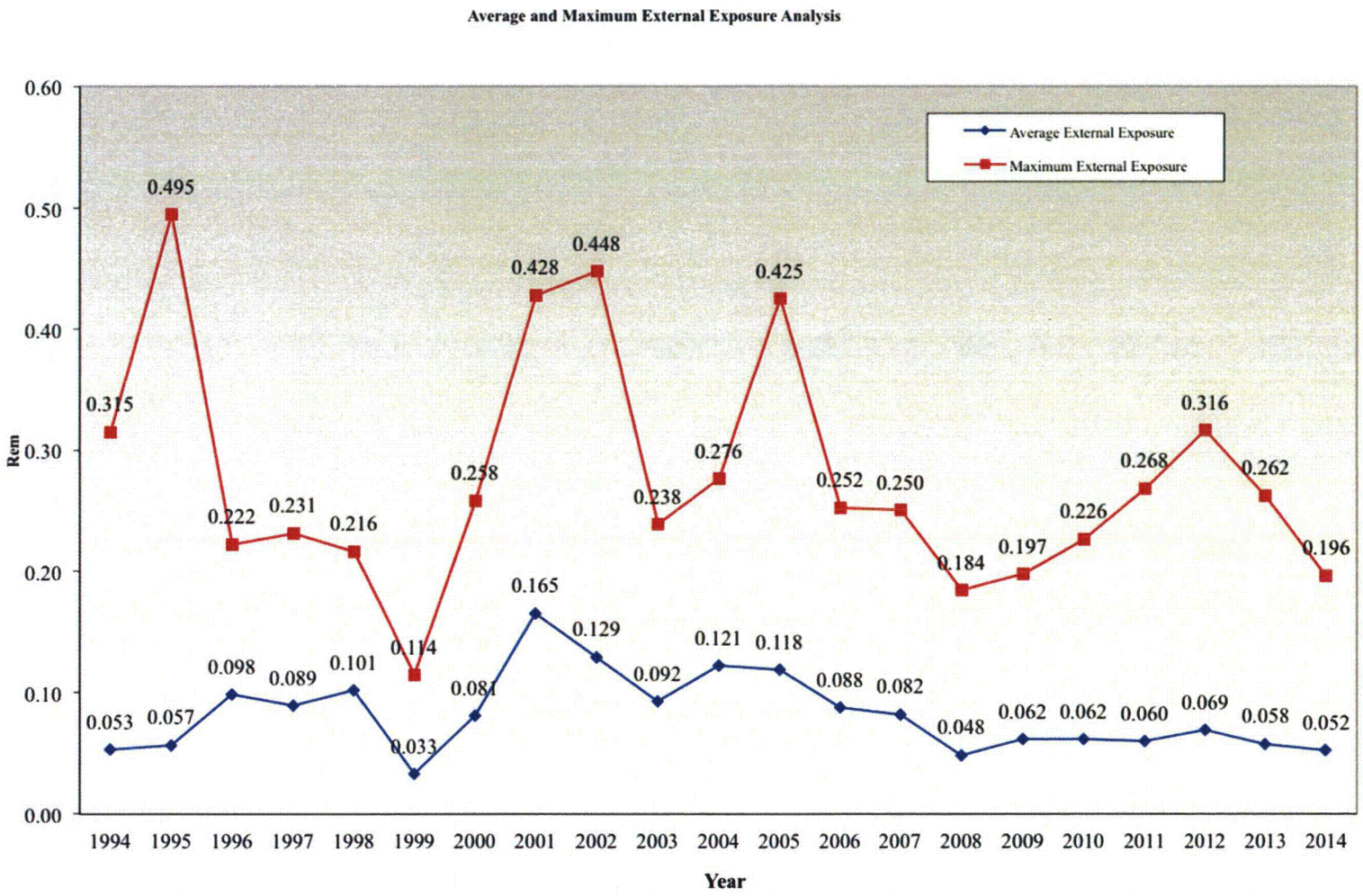

Figure A-3. Average and Maximum External Dose Analysis.

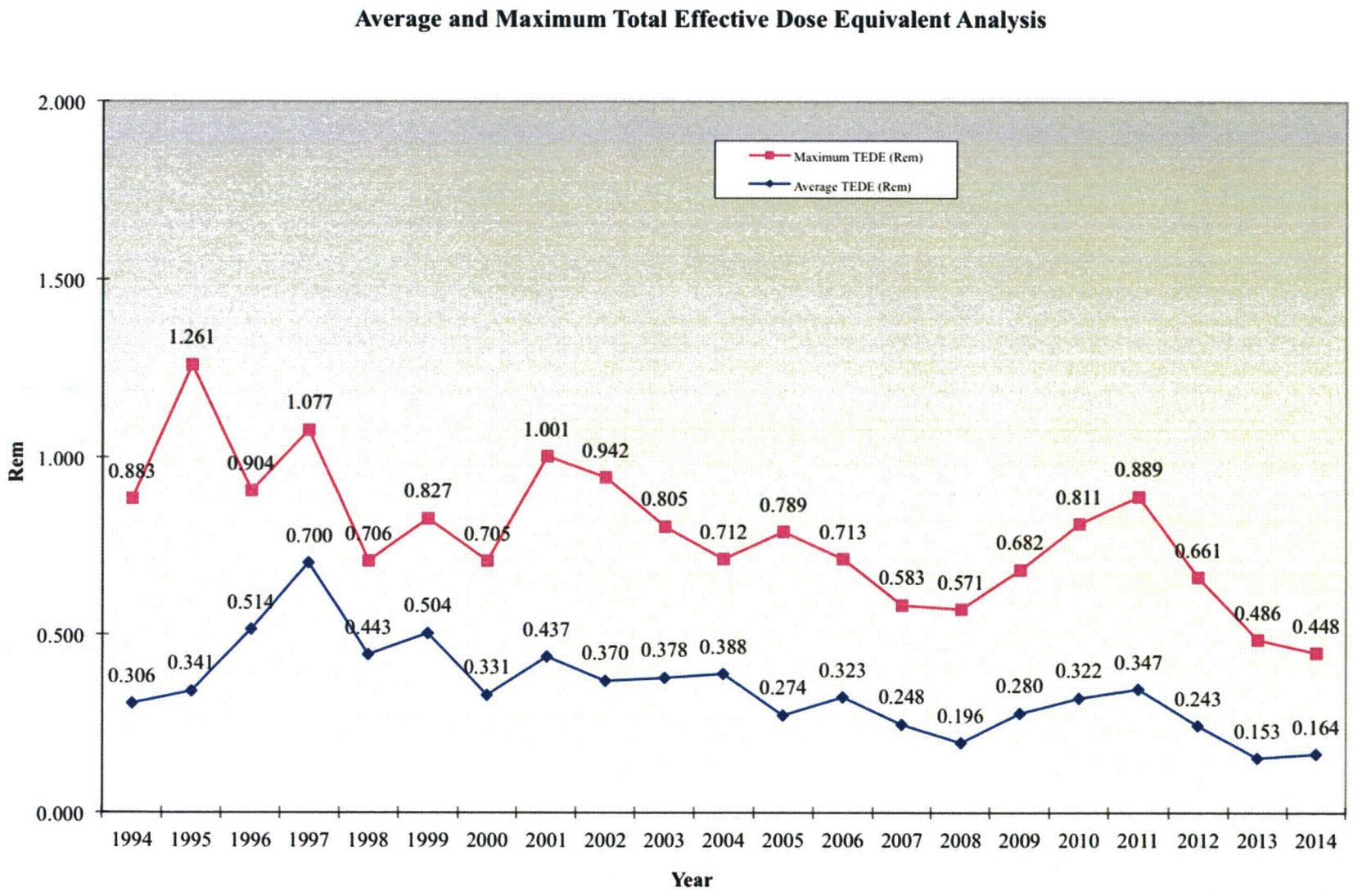

Figure A-4. Average and Maximum Total Effective Dose Equivalent Analysis.

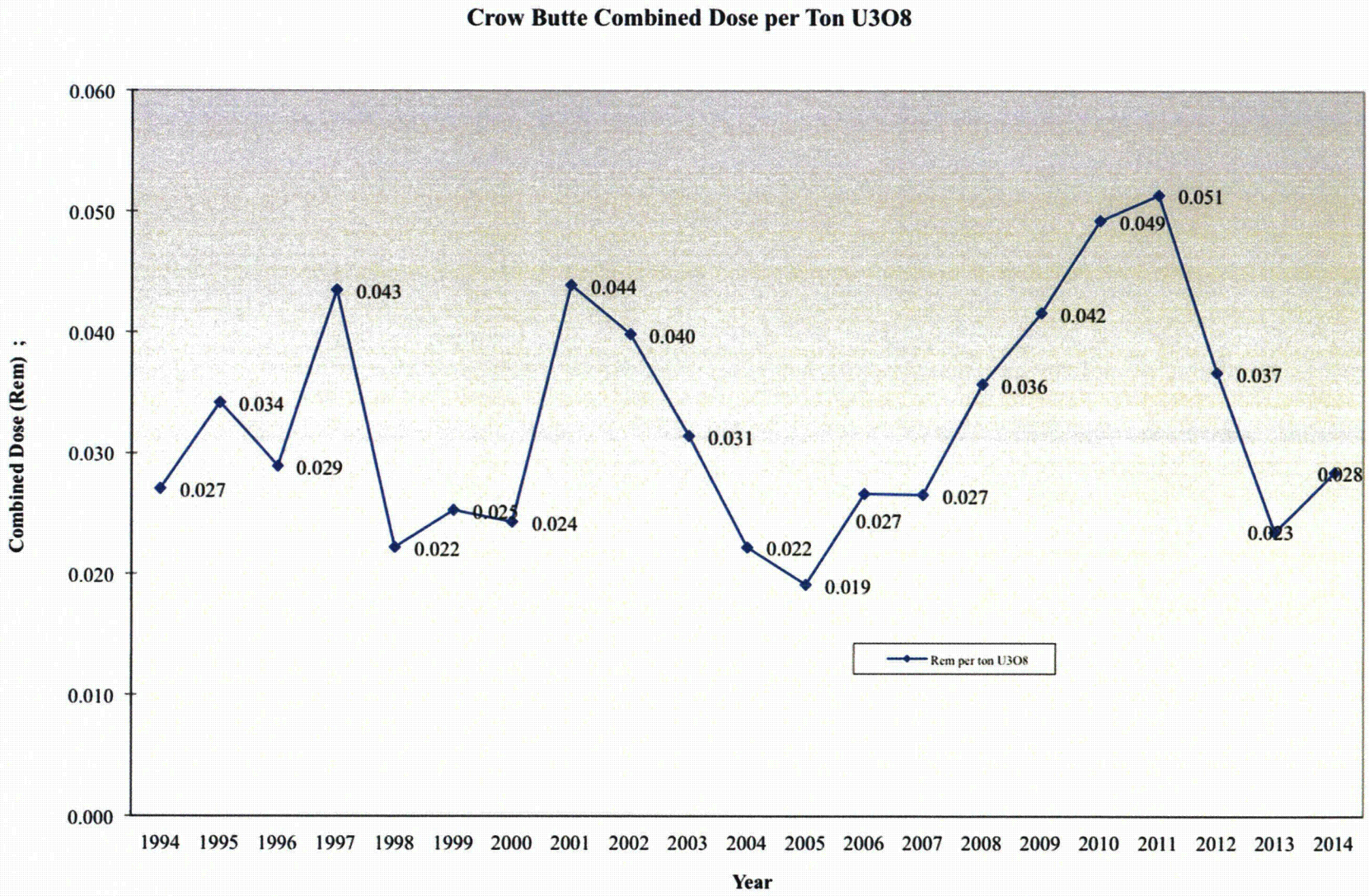

Figure A-5. Crow Butte Combined Dose (rem) per Ton U_3O_8.

APPENDIX B

Worker Radiation Dosimetry Results

Worker Dosimetry Badges must be stored in a background area. The Crow Butte worker badges and the control badge are stored on a badge board in the hallway between the lunchroom and the restricted area. This is a convenient location for workers to pick up their badges before entering the restricted area. However, the dose rate in this area is significantly elevated above background. The dose for the fourth quarter control on the badge board was 71 mrem. In contrast he control badge for the area gamma dose measurements is stored in a background area. The fourth quarter control badge dose for area gamma dose measurements was 32 mrem.

The purpose of the worker badges is to measure the dose above background that workers receive while working at the Crow Butte facility. Quarterly worker doses are calculated by subtracting the control badge dose from the worker badge dose. Since the control badge, as it is currently located, receives a dose significantly greater than background, the net worker dose is underestimated. The "missed dose" can be estimated as follows (based on fourth quarter data):

Dose rate for the badge board control = 71 mrem/2190 hours per quarter = 0.0324 mrem/hr

Background dose rate from area dosimeter control = 32 mrem/2190 hours per quarter = 0.0146 mrem/hr

The "missed dose" due to subtraction of the elevated control badge dose from the worker badge dose is the difference between the control badge dose and the measured background dose for the 520 hours when the badge is on the worker or 9.3 mrem/quarter (37 mrem per year).

The badge board should be moved to a convenient background location.