Title 40 CFR Part 191
Subparts B and C
Compliance Recertification Application 2014
for the
Waste Isolation Pilot Plant

Appendix IGP-2014
Individual and Groundwater
Protection Requirements

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Field Office
Carlsbad, New Mexico

Compliance Recertification Application 2014
Appendix IGP-2014
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Acronyms and Abbreviations

%	percent
CCA	Compliance Certification Application
CFR	Code of Federal Regulations
CH	contact-handled
Ci	curies
Ci/L	curies per liter
CRA	Compliance Recertification Application
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FEPs	features, events, and processes
gpm	gallons per minute
kg	kilogram
kg/m^3	kilogram per cubic meter
LWB	Land Withdrawal Boundary
MB	Marker Bed
mg/L	milligrams per liter
mrem	millirem
NUTS	Nuclide Transport System
PA	performance assessment
PAVT	Performance Assessment Verification Test
pCi/L	picocuries per liter
RH	remote-handled
TDS	total dissolved solids
TRU	transuranic
UP	undisturbed performance
USDW	underground source of drinking water
WIPP	Waste Isolation Pilot Plant

Elements and Chemical Compounds

Am	americium
Pu	plutonium
Ra	radium
Rn	radon
Th	thorium
U	uranium

IGP-1.0 Introduction

The quantitative release limits set forth in the containment requirements provisions of 40 CFR § 191.13 (U.S. EPA 1993) are one of three long-term numerical performance requirements contained in 40 CFR Part 191 Subparts B and C. The U.S. Department of Energy (DOE) must also comply with two other quantitative performance standards contained in the individual protection requirements (40 CFR § 191.15, U.S. EPA 1993) and groundwater protection requirements (Part 191 Subpart C). This appendix describes the DOE's demonstration of Waste Isolation Pilot Plant (WIPP) disposal system compliance with both the individual and groundwater protection requirements.

In performing the compliance assessment for the Compliance Certification Application (CCA) (U.S. DOE 1996), the CCA Performance Assessment Verification Test (PAVT) (Dials 1997a), and for subsequent Compliance Recertification Applications (CRAs), the DOE applied a bounding-analysis approach using conservative assumptions that overestimate potential doses and contaminant concentrations. To provide added assurance, the DOE assumed the presence of an underground source of drinking water (USDW) in close proximity to the WIPP Land Withdrawal Boundary (LWB), even though available data indicate that none exists near the boundary. Using this bounding-analysis approach, the maximum potential dose to an individual is 0.032 millirems (mrem) in the CCA PAVT and 0.93 mrem for the CCA evaluation (as revised, consistent with U.S. Environmental Protection Agency (EPA) direction). Both values are well below the individual protection standard [40 CFR § 191.15(a)] of 15 mrem as an annual committed effective dose. In addition, the estimated potential maximum combined radium-226 (^{226}Ra) and ^{228}Ra concentration in groundwater is 0.49 picocuries per liter (pCi/L) in the CCA PAVT and 0.14 pCi/L in the CCA Performance Assessment (PA), both well below the acceptable standard of 5 pCi/L required by 40 CFR § 191.24(a)(1) (Dials 1997a).

This bounding-analysis approach also assumes that all contaminants reaching the accessible environment are directly available to a receptor. The analysis bounds potential impacts of underground interconnections among bodies of surface water, groundwater, and any potential USDW.

In support of its 2004 Compliance Recertification Application (CRA-2004) (U.S. DOE 2004) and the 2009 Compliance Recertification Application (CRA-2009)(U.S. DOE 2009), the DOE reexamined concentrations of radionuclides that could potentially reach the accessible environment under undisturbed conditions. The CRA-2004 and CRA-2009 evaluations showed that the maximum concentration of radionuclides reaching the boundary was projected to be at least an order of magnitude less than the maximum concentration projected in the CCA analyses. Based on this and additional, updated information presented in the CRA-2004, Chapter 8.0, and again in Appendix IGP-2009, the DOE concluded that the WIPP disposal system continued to comply with the individual and groundwater protection provisions of Part 191 Subparts B and C (U.S. DOE 2004 and 2009). The EPA reviewed the information presented by the DOE in 2004 and 2009 and determined that the DOE continued to demonstrate compliance for each recertification with the individual and groundwater protection requirements of 40 CFR 191 Subparts B and C (U.S. EPA 2006, U.S. EPA 2010a and U.S. EPA 2010b).

In support of the CRA-2014, the DOE has again reexamined concentrations of radionuclides that could potentially reach the accessible environment under undisturbed conditions. The CRA-2014 PA shows no releases to the accessible boundary for the undisturbed case. Therefore, there are no radionuclide concentrations within the USDW that is conservatively assumed to exist at the WIPP boundary. The additional data gathered for this CRA continue to show that there are no USDWs within or at the WIPP accessible boundary, although they do exist some distance away. The CRA-2014 analysis continues to show that the maximum concentration of radionuclides reaching the boundary (zero for this analysis) is projected to be less than the maximum concentration projected in the CCA, which has been used for each recertification as the bounding case for compliance assessment analyses. Based on this and additional information updated for the CRA-2014 evaluation in this appendix, the DOE concludes that the WIPP disposal system continues to comply with the individual and groundwater protection provisions of Part 191 Subparts B and C.

IGP-2.0 Individual Protection Requirements

The individual protection requirements are contained in section 191.15 of the long-term disposal regulations. Section 191.15(a) requires

> Disposal systems for waste and any associated radioactive material shall be designed to provide a reasonable expectation that, for 10,000 years after disposal, undisturbed performance of the disposal system shall not cause the annual committed effective dose, received through all potential pathways from the disposal system to any member of the public in the accessible environment, to exceed 15 mrems (150 microsieverts).

Undisturbed performance (UP) is defined in Part 191 Subpart B to mean "the predicted behavior of a disposal system, including consideration of the uncertainties in predicted behavior, if the disposal system is not disrupted by human intrusion or the occurrence of unlikely natural events" (40 CFR § 191.12, U.S. EPA 1993). The CCA and CRA-2004, Chapter 6.0, Section 6.3.1 provide a description of UP, the conceptual models associated with UP, and the screening of features, events, and processes (FEPs) that are important to UP.

The method used to evaluate compliance with the individual protection requirements is related to that developed for assessing compliance with the containment requirements. This method has not changed since the CCA. If the evaluation of the UP scenario considered for the containment requirements shows contaminants will reach the accessible environment, the resulting dose to exposed individuals must be calculated and compared to the 15 mrem annual committed effective dose specified in section 191.15.

Further guidance on the implementation of the individual protection requirements is found in 40 CFR Part 194. 40 CFR § 194.51 (U.S. EPA 1996) states,

> Compliance assessments that analyze compliance with § 191.15 of this chapter shall assume that an individual resides at the single geographic point on the surface of the accessible environment where that individual would be expected to receive the highest dose from radionuclide releases from the disposal system.

40 CFR § 194.52 (U.S. EPA 1996) states,

> In compliance assessments that analyze compliance with § 191.15 of this chapter, all potential exposure pathways from the disposal system to individuals shall be considered. Compliance assessments with part 191, subpart C and § 191.15 of this chapter shall assume that individuals consume 2 liters per day of drinking water from any underground sources of drinking water in the accessible environment.

In addition, 40 CFR § 194.25(a) (U.S. EPA 1996) provides criteria related to the assumptions that should be made when undertaking dose calculations:

> Unless otherwise specified in this part or in the disposal regulations, performance assessments and compliance assessments conducted pursuant to the provisions of this part to demonstrate compliance with § 191.13, § 191.15 and part 191, subpart C shall assume that characteristics of the future remain what they are at the time the compliance application is prepared, provided that such characteristics are not related to hydrogeologic, geologic or climatic conditions.

IGP-2.1 Compliance Assessment of Undisturbed Performance

Section 194.52 specifies that compliance assessments shall consider "all potential pathways from the disposal system to individuals." The DOE has considered the following potential pathways for groundwater flow and radionuclide transport:

- Existing boreholes, as required by 40 CFR § 194.55(b)(1) (U.S. EPA 1996)
- Potential boreholes, including those that may be used for fluid injection, as required by 40 CFR § 194.32(c) (U.S. EPA 1996) and 40 CFR § 194.54(b)(2) (U.S. EPA 1996)

After considering all of these pathways, the DOE found that contaminated brine may migrate away from the waste-disposal panels if pressure within the panels is elevated by gas generated from corrosion or microbial degradation. Two credible pathways by which radionuclides could reach the accessible environment have been identified.

1. Radionuclide transport may occur laterally, through the anhydrite interbeds toward the subsurface boundary of the accessible environment in the Salado Formation (hereafter referred to as the Salado).
2. Transport may occur through access drifts or anhydrite interbeds (primarily Marker Bed [MB] 139) to the base of the shafts. If the pressure in the panels is greater than the lithostatic pressure of the overlying strata, contaminated brine may migrate up the shafts. As a result, radionuclides may be transported directly to the ground surface or laterally away from the shafts, through permeable strata, such as the Culebra Dolomite Member of the Rustler Formation (hereafter referred to as Culebra), toward the subsurface boundary of the accessible environment.

These conceptual release pathways for UP are illustrated in Appendix PA-2014, Figure PA-8. The modeling system described in Appendix PA-2014, Section PA-2.3.1 does not preclude potential radionuclide transport along other pathways, such as migration through Salado halite.

However, the natural properties of the undisturbed system make radionuclide transport to the accessible environment via these other pathways unlikely.

Although both pathways are possible, the PA modeling indicates that under undisturbed conditions, only the first is a potential pathway during the 10,000-year period of interest specified in the regulation (see Appendix PA-2014, Section PA-7.2).

The DOE has used the modeling system applied to the PA to make this determination. Scenario screening for the UP is described in Appendix SCR-2014. As specified by section 194.54(b)(2), Appendix SCR-2014 identifies activities that may occur in the vicinity of the disposal system prior to or soon after disposal, and documents which of these are included in the compliance assessment calculations. The CRA-2004, Chapter 6.0, Section 6.2, Table 6-8 identifies FEPs included in the UP modeling; these FEPs remain unchanged for the CRA-2014. Appendix SCR-2009 also identifies new FEPs that were considered, but are not identified as UP. Therefore there are no new FEPs that were identified as UP in the CRA-2014.

As specified by 40 CFR § 194.55(a), uncertainty in the performance of the compliance assessment is documented in the CRA-2004, Chapter 6.0, Section 6.1.2. Probability distributions for uncertain disposal system parameter values used in the compliance assessment were developed and are documented in Kicker and Herrick (Kicker and Herrick 2013), which identifies sampled parameters used in the compliance assessment for the CRA-2014.

For the CCA compliance assessment and all CRAs, 300 realizations of the modeling system are generated to evaluate UP. These 300 realizations are composed of three sets of 100 realizations, each generated using the Latin hypercube sampling method. None of the 300 realizations show any radionuclides reaching the top of the Salado through the sealed shafts.

In the CCA evaluation, 9 of the 300 realizations show concentrations of radionuclides greater than 0 reaching the accessible environment through the anhydrite interbeds. None of the remaining 291 realizations show radionuclides reaching the accessible environment through the anhydrite interbeds during the 10,000-year period (a realization is considered to have a negligible release if it is less than 1×10^{-18} curies per liter [Ci/L]). The maximum concentrations of radionuclides calculated by the modeling evaluation as reaching the accessible environment in the nine nonzero CCA realizations are shown in Table IGP-1. The full range of estimated values for radionuclide concentrations in the CCA evaluation is from negligible (less than 1×10^{-18} Ci/L) to the values shown in Table IGP-1. The maximum concentration values shown in Table IGP-1 occur 10,000 years after the time of decommissioning.

The maximum concentrations of radionuclides calculated by the CRA-2004, CRA-2009 and CRA-2014 evaluations that reach the accessible environment are also shown in Table IGP-1. In the CRA-2004 evaluation, only 1 of the 300 realizations shows concentrations of radionuclides greater than 0 reaching the accessible environment through the anhydrite interbeds (see Appendix PA-2004, Section PA-7.2). The remaining 299 realizations show no radionuclides reaching the accessible environment during the 10,000-year period. As with the CRA-2004 evaluation, the CRA-2009 evaluation shows that 1 of the 300 realizations results in concentrations of radionuclides greater than 0 reaching the accessible environment through the anhydrite interbeds (Ismail 2008). All of the remaining 299 realizations show no radionuclides reaching the accessible environment during the 10,000-year period. In the CRA-2014 evaluation, there were no realizations that required calculating a release concentration. Therefore all 300 realizations have no radionuclides (0 concentration) that reach the accessible environment (Kim and Camphouse 2013; see also Appendix PA-2014, Section PA-7.2).

As with all previous CRAs, the CCA dose calculations are bounding for the CRA-2014 evaluation. There were no vectors in the undisturbed scenario that passed the PA screening criteria such that all vectors had zero concentrations of actinides in the anhydrite interbeds at the accessible environment; no new dose calculations are necessary. The Nuclide Transport System (NUTS) PA computer code is used to determine releases to the WIPP boundary. It screens each vector based on a tracer concentration approach that assumes 1 kilogram (kg) of a radionuclide source is in the repository. If the calculated concentration of this radionuclide is above 1×10^{-7} kilograms per cubic meter (kg/m^3) at the boundary, it is screened in and a complete transport calculation is run for that vector with the actual radionuclide source information. None of the CRA-2014 vectors passed this screening.

It is important to understand that the magnitude of all the computed releases reported in Table IGP-1 is smaller than the effective numerical precision of the transport calculations. As explained in Lowry (Lowry 2005) and Ismail and Nemer (Ismail and Nemer 2008), the values for the single vector showing nonzero concentrations are believed to be the result of numerical dispersion inherent in the NUTS finite-difference solution method. The magnitude of the nonzero releases is indicative of numerical dispersion resulting from the coarse grid spacing between the repository and the LWB, rather than containment transport.

IGP-2.2 Dose Calculation

As quoted earlier, section 194.51 states that dose must be estimated for an individual who resides at the location in the accessible environment where that individual would be expected to receive the highest exposure to radionuclide releases from the disposal system. All potential pathways for exposure associated with the UP of the repository must be assessed (section 194.52).

Table IGP-1 Maximum Concentrations of Radionuclides Within the Salado Interbeds at the Disposal System Boundary for the CCA and CRA Analyses

CCA Realization No.	Maximum Concentrations (Ci/L)					
	Vector No.[a]	^{241}Am	^{239}Pu	^{238}Pu	^{234}U	^{230}Th
1	Replicate 1 Vector 46	1.36×10^{-17}	4.33×10^{-12}	Negligible[b]	5.82×10^{-13}	2.10×10^{-14}
2	Replicate 2 Vector 16	Negligible	5.13×10^{-14}	Negligible	6.77×10^{-15}	1.89×10^{-17}
3	Replicate 2 Vector 25	Negligible	1.35×10^{-15}	Negligible	1.65×10^{-16}	7.00×10^{-18}
4	Replicate 2 Vector 33	1.32×10^{-17}	7.18×10^{-14}	Negligible	9.76×10^{-15}	9.36×10^{-16}
5	Replicate 2 Vector 81	Negligible	6.23×10^{-18}	Negligible	Negligible	Negligible
6	Replicate 2 Vector 90	Negligible	5.20×10^{-16}	Negligible	7.40×10^{-17}	Negligible
7	Replicate 3 Vector 3	3.50×10^{-18}	3.08×10^{-13}	Negligible	4.32×10^{-14}	1.07×10^{-16}
8	Replicate 3 Vector 60	5.98×10^{-17}	7.41×10^{-14}	Negligible	9.09×10^{-15}	2.30×10^{-15}
9	Replicate 3 Vector 64	5.42×10^{-17}	5.85×10^{-12}	Negligible	7.61×10^{-13}	4.68×10^{-15}
10-300	—	Negligible	Negligible	Negligible	Negligible	Negligible
CRA-2004 Realization No.	**Vector No.**	**Maximum Concentrations (Ci/L)**				
		^{241}Am	^{239}Pu	^{238}Pu	^{234}U	^{230}Th
1	Replicate 1 Vector 82	Negligible	2.53×10^{-18}	Negligible	Negligible	Negligible
2-300	—	Negligible	Negligible	Negligible	Negligible	Negligible
CRA-2009 Realization No.	**Vector No.**	**Maximum Concentrations (Ci/L)**				
		^{241}Am	^{239}Pu	^{238}Pu	^{234}U	^{230}Th
1	Replicate 1 Vector 53	1.71×10^{-18}	3.83×10^{-13}	Negligible	1.14×10^{-15}	1.83×10^{-16}
2-300	—	Negligible	Negligible	Negligible	Negligible	Negligible
CRA-2014 Realization No.	**Vector No.**	**Maximum Concentrations (Ci/L)**				
		^{241}Am	^{239}Pu	^{238}Pu	^{234}U	^{230}Th
NA	NA	0	0	0	0	0

[a] Parameter values applied to each vector may be found in the CCA, Appendix IRES, Table IRES-2, Table IRES-3, and Table IRES-4.
[b] Values less than 10^{-18} Ci/L are considered negligible relative to the other values and are not reported.

IGP-2.2.1 Transport Pathway

To perform the required dose calculation for the CCA, it was necessary to select possible pathways for the transport of the contaminants from the anhydrite interbeds to a receptor. The chosen pathway is an abandoned, deep borehole that intersects the contaminant plume in the accessible environment. Consistent with assumptions described in the CRA-2004, Chapter 6.0, Section 6.4.7.2, and the information provided in the CCA, Appendix DEL, the hole is assumed to have the permeability of an uncased hole filled with silty sand after the degradation of a borehole plug in the Rustler Formation (hereafter referred to as the Rustler). A pressure gradient is assumed to exist because of the pressures in the anhydrite resulting from gas generation in the repository. The pressures are assumed to be greater than hydrostatic to force contaminants up the abandoned hole to the Culebra or the Dewey Lake Red Beds Formation (hereafter referred to as the Dewey Lake). The contaminants would then be available to a receptor through a well used to supply drinking water. This conceptual transport pathway is shown in Figure IGP-1. This is the only credible pathway that the DOE has been able to identify. As specified in 40 CFR § 194.54(b), this pathway considers the presence of an existing borehole.

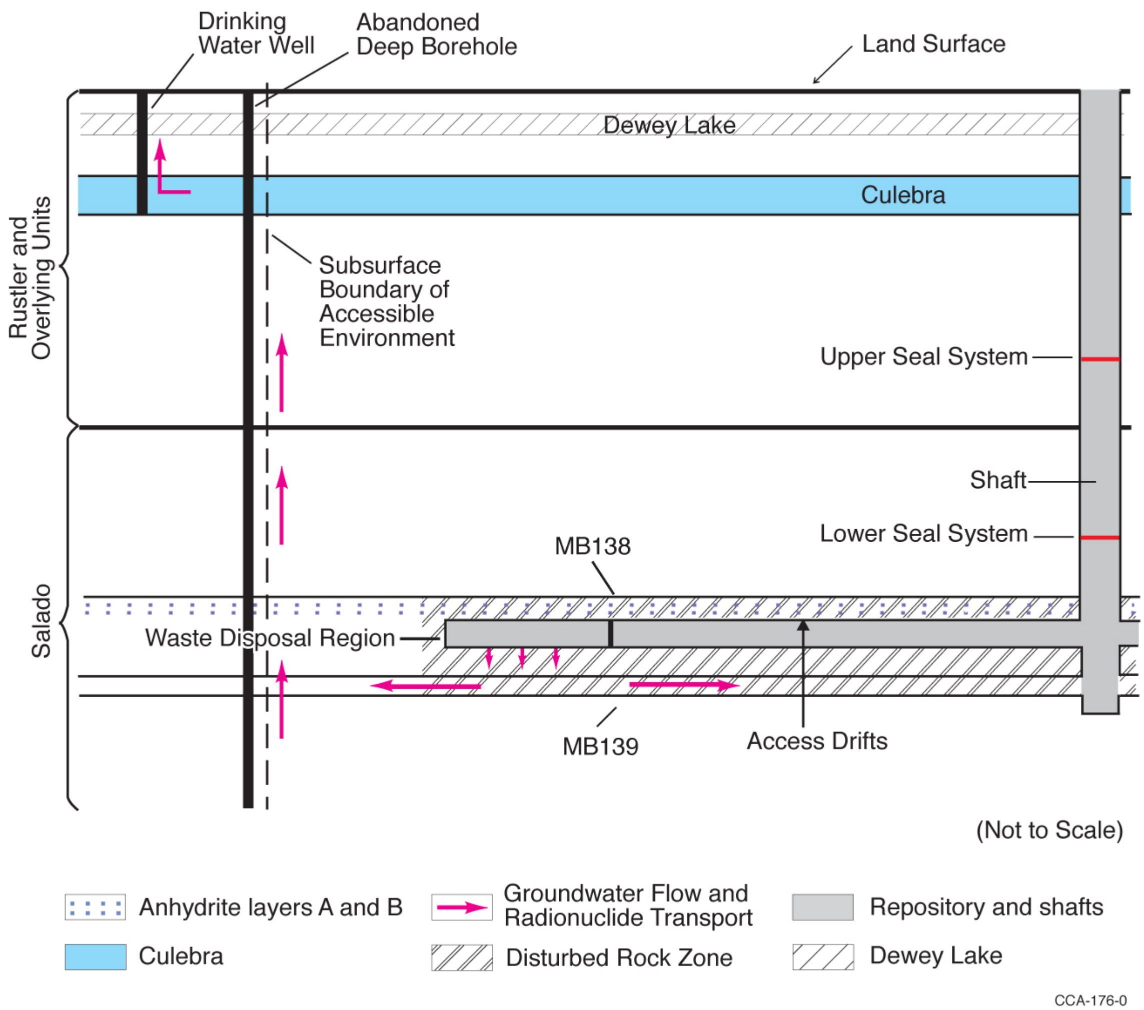

Figure IGP-1. Conceptual Transport Pathway

IGP-2.2.2 Bounding Analysis

Uncertainty in calculating radionuclide concentrations in the anhydrite interbeds is described in the CRA-2004, Chapter 6.0, Section 6.1.2, and updated for the CRA-2014 by Kicker and Herrick (Kicker and Herrick 2013). Additional uncertainty is involved in the calculation of doses resulting from the specified exposure pathway. Given this uncertainty, the DOE elected for the CCA evaluation to perform a bounding analysis using assumptions that do not represent reality, but that would result in a bounding estimate much greater than any reasonably expected dose to a receptor. If this bounding analysis results in calculated doses to the receptor that are below the regulatory limit, compliance with the standard is demonstrated. If subsequent analyses, such as those performed to support this application, have lower initial concentrations than the bounding CCA analysis, recalculating the doses is unnecessary because the results of the original bounding analysis are below regulatory limits.

The bounding analysis used for the CCA assessment was based on the following factors and assumptions:

1. No specific transport mechanism was postulated. Instead, it was assumed that all contaminants reaching the accessible environment within the anhydrite interbeds during the year of maximum releases (that is, year 10,000) were available to a receptor.

2. Brine derived from the anhydrite interbeds had total dissolved solids (TDS) concentrations of about 324,000 parts per million; this represents a concentration that could not be consumed by humans. For the bounding analysis, the calculation includes the dilution of this brine by a factor of 32.4 to a TDS concentration of 10,000 parts per million.

3. The resulting annual committed effective dose was calculated based on a 50-year dose commitment. A 50-year dose commitment was selected because this period is specified in Part 191, Appendix B, and because it is the duration for which published external dose-rate conversion factors are readily available in the literature (U.S. DOE 1988).

4. The individual receptor was assumed to drink two liters of water each day (as specified in section 194.52) for one year (in accordance with the specification of an annual committed effective dose in Part 191, Appendix B).

Section 194.51 states that the DOE shall assume an individual resides at the single geographic point where that individual would receive the highest dose. With the bounding analysis, the DOE complies with the intent of this criterion, but the specific location of the receptor is not identified because all contaminants reaching the accessible environment within the anhydrite interbeds during the year of maximum releases are assumed to be directly available to the receptor, regardless of the receptor's location. The well from which the receptor drinks is assumed to be located where the contaminants reaching the anhydrite interbeds are delivered directly to the well.

The bounding analysis dose calculation was performed using the GENII-A code. The CCA, Appendix GENII describes the modeling method. GENII-A incorporates dose-calculation guidance provided in Part 191, Appendix B.

IGP-2.3 Dose Calculation Results

The maximum doses calculated from the CCA releases listed in Table IGP-1, after applying the factors and assumptions listed above, are shown in Table IGP-2. These doses are greater than any realistic doses that could be delivered to a receptor. The calculated doses are well below the regulatory standard, which is an annual committed effective dose of 15 mrem.

Table IGP-2 Calculated Maximum Annual Committed Effective Doses for the CCA Evaluation

Realization No.	Vector No.[a]	Maximum Annual Committed Effective Dose (mrem)
1	Replicate 1 Vector 46	3.4×10^{-1}
2	Replicate 2 Vector 16	4.3×10^{-3}
3	Replicate 2 Vector 25	1.1×10^{-4}
4	Replicate 2 Vector 33	5.8×10^{-3}
5	Replicate 2 Vector 81	5.1×10^{-7}
6	Replicate 2 Vector 90	4.3×10^{-5}
7	Replicate 3 Vector 3	2.5×10^{-2}
8	Replicate 3 Vector 60	6.2×10^{-3}
9	Replicate 3 Vector 64	4.7×10^{-1}
10-300	—	Negligible[b]

[a] Parameter values applied to each vector may be found in the CCA, Appendix IRES, Table IRES-2, Table IRES-3, and Table IRES-4.

[b] Doses derived from concentration values of less than 10^{-18} Ci/L are considered negligible and are not reported.

On February 26, 1997, the DOE submitted supplementary information to the EPA in response to an EPA request for additional information (Dials 1997b, Enclosure 2h). The supplementary information describes how the DOE extended its initial bounding analysis to account for exposure pathways other than direct ingestion of contaminated water by humans. Specifically, the analysis was expanded to include consumption of contaminated water by cattle (leading to the receptor's consumption of contaminated milk and beef), consumption of crops irrigated with contaminated water, and inhalation of airborne dust from soil contaminated by irrigation. The DOE found that the contribution of these pathways added 0.46 mrem per year to the calculated groundwater dose associated with the realization showing the highest concentration of radionuclides reaching the boundary of the accessible environment under undisturbed conditions of 0.47 mrem per year. Thus, the maximum total dose calculated from all pathways was 0.93 mrem per year, well below the 15-mrem-per-year standard.

Given that the maximum concentration of radionuclides shown to reach the accessible environment for the CRA-2014 analysis is zero, resulting potential doses to the receptor would be below the 15-mrem standard. For the CRA-2014, the dose would be zero. As such, the CCA dose calculation bounded any possible dose to a receptor for the CRA-2014 evaluation.

IGP-2.4 Statistical Assessment

40 CFR § 194.55(d) specifies that the "number of estimates generated pursuant to paragraph (c) of this section shall be large enough such that the maximum estimates of doses and concentrations generated exceed the 99th percentile of the population of estimates with at least a 0.95 probability." The probability that an individual estimate is below the 99th percentile is, by definition, 0.99. This means that only 1 in 100 estimates would have a value exceeding the 99th percentile, or conversely, 99 times out of 100 the estimate would have a value below the 99th percentile. It follows that for 2 independent estimates, the probability of both estimates having a value below the 99th percentile is equal to the product (0.99)(0.99), or $(0.99)^2$, and that for n estimates, the probability that all estimates have a value below the 99th percentile is equal to $(0.99)^n$. To ensure a value exceeds the 99th percentile with a specified probability, the complement $(1 – 0.99^n)$ is used to calculate the number of estimates required.

The probability specified by section 194.55(d) is 0.95, or 95% confidence, that the maximum estimates of doses and concentrations generated exceed the 99th percentile of the population of estimates. Therefore, the following equation can be solved for n, and the number of estimates required is

$$1 - 0.99^n = 0.95 \text{ or } (n)\log(0.99) = \log(0.05) \qquad \text{(IGP.1)}$$

which implies $n > 298$.

The solution requires n to be greater than 298 and was used to determine that 300 realizations of the modeling system is a sufficient number to meet the confidence level specified in section 194.55(d).

The 300 realizations of the modeling system (as described in Section IGP-2.1) report concentrations of radionuclides reaching the accessible environment within the Salado anhydrite interbeds and not doses to a receptor, as specified by section 194.55(d). Nevertheless, the maximum possible resulting annual dose to an individual for the CCA analysis is 0.93 mrem, the sum of 0.47 mrem (as reported in Table IGP-2) plus the additional value of 0.46 mrem determined to be contributed through additional dose pathways. All other calculated doses resulting from the 300 realizations of the modeling system for the CCA, and all subsequent CRA evaluations, are below this value.

40 CFR § 194.55(f) specifies that the DOE shall

> document that there is at least a 95 % level of statistical confidence that the mean and the median of the range of estimated radiation doses and the range of estimated radionuclide concentrations meet the requirements of § 191.15 and part 191, subpart C of this chapter, respectively.

The DOE has developed a bounding analysis that exceeds the mean and median doses, providing greater than 95% confidence that all potential doses will be below the 0.93 mrem value.

IGP-2.5 Parameter Values

Parameter values applied to the CCA modeling assessment for UP are described in the CCA, Appendix PAR and Chapter 8.0, Section 8.1.5. Parameters used in the PA and compliance assessment modeling program for the CRA-2014 are described in Kicker and Herrick (Kicker and Herrick 2013). As required by 40 CFR § 194.55(b), Kicker and Herrick (Kicker and Herrick 2013) also identify the probability distributions for these parameters, their units, the models and codes in which the parameters are used, the functional form of the probability distributions used for the sampled parameters, and associated input data.

IGP-2.6 Summary of Compliance with the Individual Protection Standard

In performing the compliance assessment, the DOE applied a bounding-analysis approach using conservative assumptions that overestimate potential doses and contaminant concentrations. This conservative approach assumes that all contaminants reaching the accessible environment are directly available to a receptor. Using this very conservative approach, the calculated maximum potential dose to an individual from the CCA evaluation would be about one-sixteenth of the individual protection standard. Given that modeled maximum radionuclide concentrations in the accessible environment for all CRA evaluations are well below those of the CCA evaluation, the CCA results are bounding and continued compliance with the individual protection standard is demonstrated.

IGP-3.0 Groundwater Protection Requirements

The groundwater protection requirements are contained in Part 191 Subpart C. In particular, 40 CFR § 191.24(a)(1) requires the following:

> *General.* Disposal systems for waste and any associated radioactive material shall be designed to provide a reasonable expectation that 10,000 years of undisturbed performance after disposal shall not cause the levels of radioactivity in any underground source of drinking water, in the accessible environment, to exceed the limits specified in 40 CFR Part 141 as they exist on January 19, 1994.

40 CFR Part 141 specifies the National Primary Drinking Water Standards. The limits for radioactivity and dose equivalent based on the January 19, 1994 National Primary Drinking Water Standards are:

1. Combined ^{226}Ra and ^{228}Ra (40 CFR § 141.15(a)): 5 pCi/L

2. Gross alpha particle activity, including ^{226}Ra but excluding radon (Rn) and uranium (U): 15 pCi/L

3. Annual dose equivalent to the total body or any internal organ from the average annual concentration of beta particle and photon radioactivity from man-made radionuclides: 4 mrem per year

In addition, 40 CFR § 194.53 (U.S. EPA 1996) applies to the DOE's consideration of USDWs. The criterion specifies

> In compliance assessments that analyze compliance with part 191, subpart C of this chapter, all underground sources of drinking water in the accessible environment that are expected to be affected by the disposal system over the regulatory time frame shall be considered. In determining whether underground sources of drinking water are expected to be affected by the disposal system, underground interconnections among bodies of surface water, groundwater, and underground sources of drinking water shall be considered.

To assess compliance with these provisions of the regulations, it is first necessary to identify if any USDWs are located near the WIPP disposal system. The DOE's evaluation of whether any USDW is located near the WIPP disposal system is provided in the CCA, Appendix USDW, and is summarized in the CCA, Chapter 8.0, Section 8.2.2. In developing the CRA-2004 and the CRA-2009, the DOE reevaluated the presence of USDWs near the WIPP disposal system and supplemented the information presented in the CCA, Appendix USDW. These reviews and associated supplemental information are provided in Appendix IGP-2009, Section IGP-3.1. For the CRA-2014, the DOE has again reevaluated the presence of USDWs near the WIPP disposal system. Supplemental information is provided in Section IGP-3.2. Based on this reevaluation, the DOE again concludes that no deviation from the CCA findings and conclusions is warranted.

IGP-3.1 Criteria for USDW Determination

In evaluating the presence of any USDW, it is necessary to establish criteria for water quality and quantity data from wells in the vicinity of the WIPP disposal system. The criteria must be based on the regulatory definition of a USDW, as provided in 40 CFR § 191.22 (U.S. EPA 1993). A USDW is defined in section 191.22 to mean an aquifer or its portion that

> (1) Supplies any public water system; or
>
> (2) Contains a sufficient quantity of groundwater to supply a public water system; and
> (i) Currently supplies drinking water for human consumption; or
> (ii) Contains fewer than 10,000 milligrams of total dissolved solids per liter.
>
> "Public water system" means a system for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. Such term includes:
>
> (1) Any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system; and
>
> (2) Any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system.
>
> "Total dissolved solids" means the total dissolved (filterable) solids in water as determined by use of the method specified in 40 CFR Part 136.

Criteria based on these definitions were developed by the DOE and are used to assess the presence of any USDW near the WIPP disposal system. These criteria are defined in the sections that follow.

IGP-3.1.1 Groundwater Quantity

Since there are no public water systems in the WIPP vicinity, any possible USDW must meet the 40 CFR 191.22(2)(i) or (ii) requirements. Three subcriteria have been identified by the DOE and applied to these USDW requirements.

1. An aquifer or its portion must be capable of producing water at an adequate rate.
2. An aquifer or its portion must be capable of producing water for a sufficient duration.
3. An aquifer must contain fewer than 10,000 milligrams per liter (mg/L) of TDS.

Water-consumption information was evaluated by the DOE to define the first subcriterion (the ability to produce at an adequate rate). The value to be applied is determined by obtaining the following information:

1. The rate, over a 24-hour period, at which water is consumed by 15 service connections
2. The rate, over a 24-hour period, at which water is consumed by 25 individuals

To define a USDW, the lower of these two values is assigned by the DOE to the first subcriterion. Based on calculations presented in the CCA, Appendix USDW, a quantity of 5 gallons per minute (gpm) was assigned as the first subcriterion.

In updating these calculations for the CRA-2004 and CRA-2009, more current census data and water consumption data were obtained. The results of these calculations are found in Appendix IGP-2009, Section IGP-3.1.1. The results supported the continued use of the 5 gpm subcriteria rate. Data relating to the subcriteria rate were again reviewed for the CRA-2014 to ensure new information was consistent with the previous calculations. New census data were used; however, newer water consumption data were not available. The latest census data, the census data used in the CRA-2009, and the most current consumption data are shown in Table IGP-3.

Table IGP- 3 Per Person Household and Water Consumption Values Evaluated in the CRA-2014

Community	Persons Per Household, 2011[a] (CRA-2014)	Persons Per Household, 2001[b] (CRA-2009)	Gallons Per Capita Per Day[b]
Artesia	2.61	2.81	344
Carlsbad	2.51	2.56	271
Hobbs	2.72	2.82	257
Lovington	2.80	3.25	235
Roswell	2.58	2.58	256
Average	2.64	2.80	273

Sources: [a] U.S. Bureau of Census 2013; [b] CRA-2009, Appendix IGP, Table IGP-7

The rate derived based on 15 service connections is approximately twice the rate of that derived from 25 individuals (Appendix IGP-2009, Section IGP-3.1.1). This is because 15 service connections with 2.80 persons per household give a rate based on 42 individuals. Therefore, only the rate based on 25 individuals is necessary. Multiplying 273 gallons per capita per day times 25 people and converting to gallons per minute yields a rate of 4.74 gpm. Since the per capita data are the same as those used in the CRA-2009, this lower rate has not changed. Based on this information, it is concluded that applying the 5-gpm subcriterion is still valid for a bounding analysis. No change in this subcriterion is warranted as a result of applying the most current census data.

The definition of the second quantity subcriterion (the acceptable production duration of a well) is more subjective. Because the creation of a public water supply system involves considerable capital expense, it is reasonable to assume that such a water system would not be constructed unless the water source would continue to be available for some time, at least long enough to recover the capital expense. The Rural Utility Service of the U.S. Department of Agriculture provides loans to fund new rural water supply systems. The loan periods are generally 40 years in duration. Based on this, a duration of 40 years is applied by the DOE to the second quantity subcriterion. This is the same assumption that has been used since the CCA.

IGP-3.1.2 Groundwater Quality

A criterion of 10,000 mg/L of TDS is specified in section 191.22. Any aquifer or its water-producing portion with TDS concentrations below this level is determined to produce water that meets the quality criterion for a USDW. Any aquifer or its water-producing portion with TDS concentrations at or above this level is determined to produce water that does not meet the quality criterion and the regulatory definition of a USDW.

IGP-3.2 Comparison with USDW Determination Criteria

Previous analyses of water quality in the WIPP site characterization and groundwater investigation wells have determined that there are wells with groundwater TDSs below 10,000 mg/L in the WIPP vicinity. The WIPP vicinity is the area where these WIPP wells are located outside of the WIPP LWB. The WIPP LWB is the regulatory compliance point for individual and groundwater protection. Although for conservatism the DOE assumes there is a USDW at the WIPP boundary, analyses of available data concluded that no wells within the WIPP and at the boundary meet the criteria or definition of a USDW. These analyses are document in Appendix IGP-2009, Section IGP-3.2. There were no new wells drilled at new locations in the WIPP vicinity, only replacement wells (information on these wells are provided in Appendix HYDRO-2014, Section HYDRO-4.0). As such, there is no new information to assess for a USDW determination. No additional investigations were performed as part of the CRA-2014. Based on this review, no modification of the USDW determinations reported in the CCA, Appendix USDW is warranted. The DOE continues to conclude that there are no USDWs at the WIPP accessible boundary; however, in the vicinity of the WIPP disposal system, USDWs are present in the Culebra, and potential USDWs are present in the Dewey Lake and the Santa Rosa.

IGP-3.3 Comparison with the Limits Found in 40 CFR 141 as they Existed on January 19, 1994

To provide additional assurance of the safety of the WIPP disposal system, the DOE prepared a bounding assessment of the concentrations of contaminants that could occur in a nearby USDW. Bounding doses that could be received by drinking from the USDW are also calculated. As with the individual protection standard, the analysis is bounding; the results illustrate the maximum, yet unrealistic, concentrations of contaminants in a hypothetical USDW and the maximum, yet unrealistic, resulting doses. As with the dose calculations, maximum concentrations were summed to develop concentrations for comparison with the limits found in 40 CFR 141 as they existed on January 19, 1994. The conclusions of this work, provided below, illustrate that the consequences of the undisturbed repository are negligible, even when conservative assumptions are applied to the performance evaluation. Because a hypothetical USDW is assumed to exist at the site boundary in these analyses, the results of the bounding analysis support the position that additional characterization of groundwater near the WIPP disposal system to make a more definitive USDW determination is not warranted.

IGP-3.3.1 Transport Pathway

Section IGP-2.2.1 describes the transport pathway assumed for the bounding analysis performed to evaluate compliance with the individual protection standard. This same transport pathway is assessed to evaluate compliance with the groundwater protection standard.

This pathway assumes that a hypothetical USDW is located where the maximum possible concentration of radionuclides could be realized in the USDW and the maximum possible dose to an individual who drinks from the USDW could be delivered to the individual. As such, the analysis bounds the section 194.53 criterion specifying that the DOE must consider underground interconnections among bodies of surface water, groundwater, and USDWs.

IGP-3.3.2 Combined ^{226}Ra and ^{228}Ra

The modeling system employed to simulate the performance of the undisturbed repository tracks the transport of the most important radionuclides to releases in the accessible environment (see Appendix PA-2014, Section PA.2.1.3). These radionuclides, listed in Table IGP-1, are americium-241 (^{241}Am), plutonium-239 (^{239}Pu), ^{238}Pu, ^{234}U, and thorium-230 (^{230}Th). They do not include ^{226}Ra or ^{228}Ra because these radionuclides are not a prevalent component of the projected inventory (Kicker and Zeitler 2013). However, an analysis of ^{226}Ra and ^{228}Ra is required to evaluate compliance with the groundwater protection standard.

To perform the bounding analysis for previous CRAs, the results of a NUTS code tracer exercise were used to scale the anticipated releases of ^{226}Ra and ^{228}Ra. The tracer exercise would screen in any vector with an initial 1 kg/m^3 concentration of radionuclides in the repository that resulted in a concentration at the accessible environment boundary with a concentration greater than 1.0×10^{-7} kg/m^3. By applying this scaling factor to the quantity of ^{226}Ra and ^{228}Ra projected to be emplaced in the repository, it was determined and reported in the CRA-2004 that the maximum concentration of these radionuclides in the accessible environment is 0.07 pCi/L (Wagner 2003), which is below 5 pCi/L.

This concentration was calculated by transporting the passive tracer in the flow field generated using the BRAGFLO code for Realization 1 (Replicate 1, Vector 82), shown in Table IGP-1. The calculation uses the mass and activity loads for ^{226}Ra and ^{228}Ra in the radionuclide inventory at closure and at 10,000 years. These values are provided in Table IGP-4. The ORIGEN 2.2 code was used to calculate the activity loads at 10,000 years; these loads are 51.43 curies (Ci) of ^{226}Ra in contact-handled transuranic (CH-TRU) and remote-handled transuranic (RH-TRU) waste and 7.95 Ci of ^{228}Ra in CH-TRU and RH-TRU waste. The calculated concentration is based on the volume of brine, 5,577 cubic meters (169,924 cubic feet), in the repository at time zero in the BRAGFLO calculation.

Table IGP- 4 Total Inventory and Mass Loading of ^{226}Ra and ^{228}Ra Reported in the CRA-2004

Radionuclide	Waste Type	Total Inventory at Closure (Ci)	Total Inventory at 10,000 Years (Ci)	Mass Loading (kg)
226Ra	CH	6.28 × 100	4.98 × 101	6.35 × 10-3
226Ra	RH	4.99 × 10-5	1.63 × 100	5.05 × 10-8
228Ra	CH	7.63 × 100	7.70 × 100	2.81 × 10-5
228Ra	RH	2.51 × 10-1	2.54 × 10-1	9.23 × 10-7

Source: (Fox 2003)

The total concentration (CH-TRU and RH-TRU) of either ^{226}Ra or ^{228}Ra at 10,000 years at the accessible environment boundary was calculated using the following steps:

1. Calculate the total mass load at 10,000 years by multiplying the total mass load at decommissioning by the ratio of activity loadings at 10,000 years and decommissioning, respectively.

2. Calculate the total mass concentration at the accessible environment boundary by dividing by the value of brine from the BRAGFLO simulation and multiplying by the NUTS scaling factor.

3. Convert to total concentration of activity at the accessible environment boundary by multiplying by the ratio of activity loading to mass loading at decommissioning.

4. Divide the concentration by the dilution factor 32.4 (see Section IGP-2.2.2).

The 0.07 pCi/L maximum concentration calculated for the CRA-2004 occurs in the anhydrite interbeds within the Salado and not in a zone that could realistically be a source of drinking water.

In the CCA, this value is reported as 2 pCi/L. During the PAVT (U.S. DOE 1997), it was determined that the CCA calculation used an inappropriate brine volume value and failed to account for the dilution factor. Accordingly, the PAVT analysis shows that the correct value that should have been reported in the CCA is 0.14 pCi/L (Dials 1997a).

For the CRA-2009, a new derivation concept was applied to demonstrate that the combined ^{226}Ra and ^{228}Ra concentrations were below the regulatory limit of 5 pCi/L over the 10,000-year performance period (Ismail and Nemer 2008). The new method better represented the actinide concentration at the LWB because it did not use the cumulative tracer scaling factor. Current PA calculations do not explicitly track Ra concentrations in the groundwater, so an alternate method was first used in the CCA to derive conservative estimates of potential Ra concentrations at the LWB. This method was also used in the CRA-2004. The original method overestimated the potential Ra concentration because the estimates used a cumulative scaling factor. An alternate method was chosen that is more consistent with the methods used to calculate actinide concentrations in PA.

As described in Section IGP-2.1, Ismail (Ismail 2008) identifies only one vector in the CRA-2009 PA that had nonzero releases at the LWB. Replicate 1, Vector 53 showed a tracer concentration in the MB at the LWB of 1.24×10^{-4} kg/m^3 (Ismail 2008). The maximum concentrations of radionuclides at the LWB during the 10,000-year regulatory period are shown in Table IGP-1.

As stated above, the Ra concentration was not previously calculated in PA. However, a new analysis was performed using the current PA methods and including Ra. The analysis shows a maximum ^{226}Ra concentration of 1.7×10^{-5} pCi/L for the CRA-2009 PA and 6.5×10^{-7} for the CRA-2004 PABC. These concentrations of ^{226}Ra are more than five orders of magnitude below the regulatory limit of 5 pCi/L (Ismail 2008).

For the CRA-2014, no Ra concentration was calculated or predicted. No vectors passed the NUTS screening for the undisturbed scenario such that there were no radionuclide concentrations above zero at the accessible boundary (Kim and Camphouse 2013). Based on this information, continued compliance with the combined ^{226}Ra and ^{228}Ra standard is demonstrated.

IGP-3.3.3 Gross Alpha Particle Activity Including ^{226}Ra but Excluding Rn and U

For the CCA evaluation, compliance with the groundwater protection standard was assessed by summing the maximum concentration values provided in Table IGP-1 for ^{241}Am, ^{239}Pu, ^{238}Pu, and ^{230}Th and adding the CCA value for ^{226}Ra obtained to perform the section IGP-3.3.2 assessment. The value obtained by this method is 7.81 pCi/L, which is below the section groundwater protection standard of 15 pCi/L. This concentration occurs in the anhydrite interbeds within the Salado and not in a zone that could realistically be a source of drinking water.

For the CRA-2004 evaluation, the only contributing radionuclide was ^{239}Pu, with a concentration of 2.53×10^{-6} pCi/L. This value, summed with the 0.07-pCi/L value derived for the section IGP-3.2.2 assessment, was essentially 0.07 pCi/L, well below the 15-pCi/L standard.

For the CRA-2009 evaluation, there were four contributing radionuclides with a total concentration of 3.84×10^{-1} pCi/L (Table IGP-1). As with the CRA-2004 analysis, this value, when summed with the 1.7×10^{-5} pCi/L value derived for the section IGP-3.2.2 assessment, remains essentially 3.84×10^{-1} pCi/L, well below the 15-pCi/L standard.

As described above, no contribution from ^{226}Ra is expected. The gross alpha particle activity including ^{226}Ra and excluding Rn and U is expected to be zero.

For the CRA-2014, no radionuclide concentrations are expected at the boundary over the regulatory time frame for the undisturbed scenario. As such, no additional analyses were performed. The gross alpha particle activity, including ^{226}Ra and excluding Rn and U, is again expected to be zero.

Continued compliance with the Gross Alpha Particle Activity Including ^{226}Ra But Excluding Rn and U standard is demonstrated.

IGP-3.3.4 Annual Dose Equivalent to the Total Body or Any Internal Organ from the Average Annual Concentration of Beta Particle and Photon Radioactivity from Man-made Radionuclides

To assess compliance with the total annual dose to the total body or any internal organ standard, an annual dose equivalent of 4 mrem per year, the transport of ^{239}Pu, ^{238}Pu, ^{234}U, and ^{230}Th was evaluated. The maximum annual committed effective dose calculated for the CCA evaluation from any of these radionuclides was 0.93 mrem, which is the value reported for transport through MB 139 and is well below the regulatory standard. The 0.93 mrem value includes alpha particle radioactivity, as well as beta particle and photon radioactivity. Thus, the value is very conservative, as the 4-mrem annual dose equivalent limit is only for beta particle and photon radioactivity.

By comparison, the maximum radionuclide concentration in the accessible environment calculated for the CRA-2004 evaluation was six orders of magnitude less than the maximum bounding value calculated for the CCA. Resulting doses for the CRA-2004 case would be correspondingly lower, as well.

For the CRA-2009 evaluation, the maximum radionuclide concentration in the accessible environment was one order of magnitude less than the maximum bounding CCA value. As such, resulting doses for the CRA-2009 case would be correspondingly lower, and continued compliance with the total annual dose to the total body or any internal organ standard is demonstrated.

The CRA-2014 calculations show that no radionuclides reach the accessible environment in the undisturbed scenario over the 10,000-year regulatory time period. As such, the CCA results continue to be bounding for the CRA-2014; continued compliance with the individual protection standard is demonstrated.

IGP-4.0 Compliance Summary

In performing the compliance assessment, the DOE applied a bounding-analysis approach using assumptions that overestimate potential doses and contaminant concentrations. To provide added assurance, the DOE assumed the presence of a USDW in close proximity to the WIPP LWB, even though available data indicate that none currently exists near the boundary. Using this bounding-analysis approach, the calculated maximum potential dose to an individual determined for the CCA evaluation would be about one-sixteenth of the individual protection standard.

For the CRA-2014 evaluation, the potential dose would be zero, which remains below the CCA value, and continued compliance with the individual protection standard is maintained. The potential concentrations of contaminants in the hypothetical USDW and the maximum potential dose to a receptor that drinks from the hypothetical USDW continue to be bounded by the CCA analysis.

This approach also conservatively assumes that all contaminants reaching the accessible environment are directly available to a receptor. The analysis bounds any potential impacts of underground interconnections among bodies of surface water, groundwater, and USDWs.

IGP-5.0 References

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