ENERGYSOLUTIONS

December 27, 2023

CD-2023-248

Mr. Doug Hansen, Director
Division of Waste Management and Radiation Control
P.O. Box 144880
Salt Lake City, UT 84114-4880

Subject: Federal Cell Facility Application - Responses to Request for Information– DRC-2023-004939

Dear Mr. Hansen:

Energy*Solutions* hereby responds to the Utah Division of Waste Management and Radiation Control's June 13, 2023 Request for Information (RFI) on our Federal Cell Facility Application.[1] A response is provided for each request using the Director's assigned reference number.

Appendix W: Surety

W-1: ***Please provide information that details the surety listed in Appendix W of the Federal Cell License Application. It appears to be representative of the transfer of the Depleted Uranium (DU) from the DU Storage Building to the Cell, with no additional waste placement.***

Utah Administrative Code (UAC) R313-25-31(1) requires Energy*Solutions* to provide assurances prior to the commencement of Federal Cell Facility operations that sufficient funds will be available to carry out land disposal facility closure and stabilization at the Facility's current condition. The projected surety amount is evaluated and adjusted annually to reflect changes in conditions of the Federal Cell Facility and material and labor costs. Current calculations in Appendix W project the amount of financial surety needed for:

- Construction of sufficient cell capacity (63,800 square feet of liner) to the specifications required in Work Element, *Clay Liner Placement* in the Federal Cell Facility Construction Quality Assurance / Quality Control (FCF CQA/QC) Manual (found in Appendix C to the Federal Cell Facility Radioactive Material License);
- Transfer of the 5,408 drums of undisposed federal contaminated material in storage at Clive (received from U.S. Department of Energy [DOE] Savanah River Site) into the Federal Cell Facility to the specifications required in Work Element, *Depleted Uranium Waste Placement* in the FCF CQA/QC Manual (Appendix C to the Federal Cell Facility Radioactive Material License);
- Infill of the placed drums with 4,537 cubic yards of Controlled Low-Strength Material (CLSM);
- Placement of 110,031 cubic yards of clean fill above the CLSM-entombed depleted uranium to the specifications required in Work Elements, *Fill Placement with Compactor* or *Fill Placement without Compactor* in the FCF CQA/QC Manual (Appendix C to the Federal Cell Facility Radioactive Material License);
- Construction and settlement monitoring of 23,519 square feet of Temporary Cover;
- Completion of 46,834 square feet of final cover over the Federal Cell Facility to the specification required in Work Elements *Radon Barrier Placement, Frost Penetration*

[1] Hansen, D.J. "Federal Cell Facility Application Request for Information." via DRC-2023-000525 from the Utah Division of Waste Management and Radiation Control to Vern Rogers of Energy*Solutions*, June 13, 2023.

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Layer Placement, Filter Zone (Side Slope), Rock Erosion Barrier (Side Slope), and Surface Zone Layer Material Placement in the FCF CQA/QC (Appendix C to the Federal Cell Facility Radioactive Material License);
- Construction of 2,000 feet of perimeter fencing around the Federal Cell Facility;
- Perform required post-closure monitoring and maintenance activities; and
- Transition long-term care stewardship of the Federal Cell Facility to DOE.

The volume of unplaced waste included in the Federal Cell Facility surety calculations serves as a compliance point, limiting the volume of waste requiring placement to less than the funds secured in surety. Prior to disposal of federal waste beyond that currently in storage at the Clive Facility, Energy*Solutions* acknowledges that revision of this estimate will be required.

W-2: ***A premature closure plan for the Federal Cell is not included in the application. The surety will require a review and update when a premature closure plan is submitted.***

In accordance with the requirements of UAC R313-25-8(7), the Federal Cell Facility is designed and will be constructed to facilitate disposal site closure and to eliminate the need for active maintenance after closure. Principal design features and their characteristics are chosen to support the final condition that the facility and its components achieve stability and minimize any unlikely environmental releases after closure.

Premature closure of the Federal Cell will proceed in accordance with the Site Closure Plan (Section 5 of the Federal Cell Facility Radioactive Material License Application) and FCF Decontamination and Decommissioning Plan (Appendix L to the Federal Cell Facility Radioactive Material License Application). All federal waste placement and Federal Cell Facility construction activities associated with premature closure will be conducted in accordance with the specifications required by the FCF CQA/QC Manual (found in Appendix C to the Federal Cell Facility Radioactive Material License Application).

The Federal Cell Facility will be prematurely closed after any stockpiled depleted uranium has been placed within the Facility and infilled with CLSM. Any additional clay liner will be constructed to accommodate disposal of stockpiled depleted uranium. Interim fill will be placed and compacted. An interim cover system will be applied and allowed to settle, consolidate, and stabilize for at least one year. Once the interim cover is demonstrated to be stable within acceptable limits, settlement monitors will be placed, and the final cover system constructed. Any on-site support facilities constructed to solely support operations at the Federal Cell Facility will be decommissioned and demolished. As is presented in the FCF Decontamination and Decommissioning Plan (Appendix L), decommissioning and demolition are expected to involve the following activities: decontamination as necessary prior to release, demolition, disposal on site, release for unrestricted use, and restoration to required final condition. Once all federal decommissioning waste requiring on-site disposal has been placed in the Federal Cell Facility, the interim cover will be placed and monitored as required for differential settlement.

W-3: The surety in Appendix W included a non-approved cover design. The surety will require a review and potential update when an approved cover is designated.

UAC R313-25-31(1) requires Energy*Solutions* to estimate the funds necessary to close the Federal Cell Facility using the design proposed in Section 3 of the Federal Cell Facility Radioactive Material License Application and perform subsequent maintenance and monitoring. The proposed facility construction and cover designs will be approved as part of granting the Radioactive Material License. Energy*Solutions* acknowledges that closure and post-closure cost estimates may require revision if the final Federal Cell Facility and cover designs in an awarded Radioactive Material License differ from those currently being proposed.

W-4: ***The Surety in Appendix W appears to be for the year 2020. The surety will require a review and update before the Federal Cell is put into service.***

Utah Code §19-3-104(12)(f)(ii) allows Energy*Solutions* to determine closure and post-closure costs based on "*…a competitive site-specific bid for closure and post-closure care of the facility at least once every five years.*" At the time they were prepared, the Federal Cell Facility closure and post-closure cost estimates included in Appendix W were developed from the current approved competitive site-specific surety bid for the Clive Facility.[2] As is common with sureties for other operations at the Clive Facility, Energy*Solutions'* acknowledges that annual revisions will need to reflect changes in Federal Cell Facility construction activities, site conditions and inflation.

<u>**Appendix AB: Operational Period Modeling**</u>

AB-15: ***Page 1 of Appendix AB states that a leach rate of 0.01/yr. is assigned "to account for the DU being containerized when placed in the disposal cell," and "results in delayed leaching to groundwater and higher contaminated zone soil concentrations." However, Sections 6.1.3.1, 6.1.3.2, 6.1.3.3, and 6.1.3.5 of the RML Application state that the concentration estimates "[do] not take credit for the DU waste containers and therefore is likely to overestimate releases." Please address this inconsistency between the text of the application and the text of Appendix AB, as well as a justification for the assigned leach rate.***

In response to RFI AB-18, Neptune prepared Revision 2 of "Clive Operational Period RESRAD Analysis" dated December 2023. In this work, K_d-based leach rates have been applied to all radionuclides. Practically, this means that no "credit" is taken for the effect of a container in controlling the availability of any radionuclide for release to the environment.

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[2] Orton, T., "11e.(2) Radioactive Material License UT 2300478, 2020 Annual Report." (CD-2021-060) Report from EnergySolutions to Jalynn Knudsen of the Utah Division of Waste Management and Radiation Control. April 30, 2021.

AB-16: ***Examination of the RESRAD files show that the model was run for a 50 year operational period; however, text statements of the operational period within Appendix AB are inconsistent. For example, the Groundwater section on page 2 states "…within 50 years of operations…" and "…within an assumed 20-year operating period…," and the Pond Biota section states, "Over a 20-year modeling period…" Additionally, every graph included in the appendix appears to include data up to approximately 25 years. Please revise the text to include a consistent representation of the assumed operational period and resulting data.***

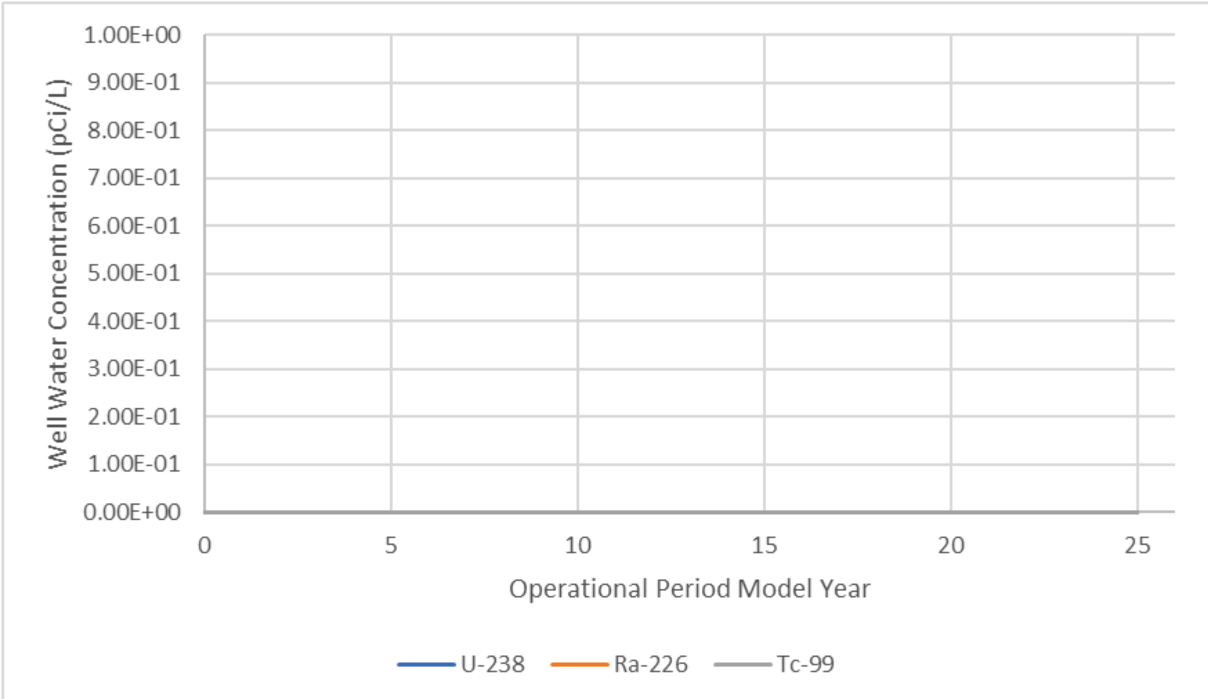
As noted by the reviewer, RESRAD-Offsite was run for 50 years. This was done so that results are available for longer operational periods, if desired. In the report, results are displayed to 25 years to facilitate evaluating trends, if any, beyond the assumed 20-year operational period. Text explaining this has been added to the introduction and clarifying edits have been made throughout.

AB-17: ***The graph in the Groundwater section, on page 2, does not adequately display the relevant information discussed in the preceding text. It indicates that Tc-99 reaches groundwater at approximately year 35, and that the well Tc-99 concentration is approximately 0.006 pCi/L at 40 years; however, the x-axis (abscissa) does not reach these time periods, and the y-axis (ordinate) is excessively large. Please revise the graph to appropriately reflect all modeled data.***

The anticipated duration of the operational period for the Federal Cell Facility is 20 years. Model results were generated and graphically displayed for a 25-year period. Because no radionuclides reach groundwater during the 25-year modeling timeframe the scale of the y-axis for well water concentrations was simply set as 0 to 1 pCi/L. The revised RESRAD-OFFSITE model applies the 1-ft clay layer (referred to as Liner Protective Cover in the facility design) that will be required above the 2-ft engineered clay liner, resulting in significantly longer times before any contaminants reach groundwater (assuming no cover exists and taking no credit for containers restricting release of radionuclides to groundwater).

Relevant text and the graph from Revision 2 of "Clive Operational Period RESRAD Analysis" dated December 2023 is reproduced below:

1. Well Water Radionuclide Concentrations. No breakthrough of any radionuclides at the well located 90 ft from the edge of the contaminated zone occurs within the operational period for any of the four open operational area cases evaluated. Even assuming no cover is placed on the disposed DU waste, and taking no credit for containerization, breakthrough of Tc-99 at the well does not occur until model year 200 in the RESRAD-OFFSITE evaluation. Longer-term modeling of releases to groundwater from the closed disposal cell is the subject of the DU PA.



AB-18: ***Please provide justification that the use of the RESRAD default values for the applicable parameters listed in the parameters values table is descriptive/accurate for the site. Additionally, the parameter table of Appendix AB indicates that the Kd values of the contaminated zone in RESRAD are equal to the deterministic Kd values of Unit 3 (sand) material from the Goldsim model. However, the RESRAD contaminated zone porosity and dry bulk density are set to RESRAD default values of 0.4 and 1.5 g/cm3, respectively, which do not match the corresponding parameters for Unit 3 in Goldsim (0.393 and 1.609 g/cm3). Please provide justification for the use of the default values or rectify the RESRAD model.***

In response to RFI AB-18, the “Clive Operational Period RESRAD Analysis” is re-issued as Revision 2 dated December 2023. In Revision 2 of the analysis, Unit 3 porosity and dry bulk density values (0.393 and 1.609 g/cm^3 respectively) in the revised modeling are the mean of the distribution used in the GoldSim DU PA model. No other changes have been made to the “Clive Operational Period RESRAD Analysis” from revision 1 dated May 2023.

AB-19: ***The RESRAD model has an unsaturated zone hydraulic conductivity set to 227 m/yr. (or 7.2E-4 cm/s). However, in the Goldsim model, the hydraulic conductivity of the unsaturated zone has a mean of 5.15E-5 cm/s. Please provide information that addresses the difference in hydraulic conductivities between the two models.***

The RESRAD native UZ conductivity is for a silty loam soil texture and is referenced to RESRAD guidance. The value used in the “Clive Operational Period RESRAD Analysis,” Revision 2 is about 14x larger than the mean value used in the GoldSim DU PA model. Since there is no breakthrough to groundwater using the larger value, changing hydraulic conductivity to the (smaller) GoldSim mean and further delaying breakthrough time will have no impact on the RESRAD modeling results.

AB-20: ***The dimensions provided for the Federal Cell in Appendix O are 374 m by 585 m, but in the RESRAD model the active area modeled was only 30.48 m by 30.48 m. Even though a smaller portion of the overall cell may be open at a given time for waste placement, it is likely that an area larger than this will contain waste for a majority of the operating period. Please provide justification for the modeled contamination zone dimensions. Similarly, the length parallel to aquifer is set to 30.48 m; however, for a majority of the Federal Cell's operational period, it is likely that a longer portion of the cell will contain waste. Please provide justification for these parallel dimensions.***

The operational contaminated zone in RESRAD-OFFSITE was initially represented as a 100 ft by 100 ft (30.48 m by 30.48 m) disposal cell with a waste thickness of 1m (roughly equivalent to the height of a container used for shipping DU). These dimensions pertain to the waste actively being placed within the embankment (assumed to be directly affected by transport via leaching, surface water runoff, and atmospheric dispersion with no influence of temporary or final cover).

In the "Clive Operational Period RESRAD Analysis," Revision 2, the 2.4-m thickness of the completed disposal cell equivalent to that assumed in the DU PA has been applied. In addition to modeling of radionuclide transport from an assumed open disposal area of 100 ft by 100 ft, the effects of differing operational disposal practices are examined by modeling performed for varied open disposal areas of one-quarter, one-half, and 100% of the DU placement area of the Federal Cell.

AB-21: ***The clay liner unsaturated zone included in the RESRAD model is set to a thickness of 1 foot; however, Section 1.2.3 of the application states the clay liner is 2 feet. Please clarify which clay liner will be used and provide justification for the chosen thickness.***

The "Clive Operational Period RESRAD Analysis," Revision 2 applies a 1-foot clay liner protective cover layer above a 2-foot engineered clay liner between the disposed waste and the native unsaturated zone.

AB-22: ***There are several citations included in the table of RESRAD parameter values, but no reference list is provided. Please include a complete list of references cited in this appendix.***

The "Clive Operational Period RESRAD Analysis," Revision 2 includes a reference list.

AB-23: ***If model parameters change in response to RFIs, please re-run the model and provide updated results.***

The model was previously revised and reissued in May 2023 in response to RFIs AB-2 through AB-14, received under cover letter dated April 24, 2023.[3] The model has been revised again and is reissued as "Clive Operational Period RESRAD Analysis," Revision 2, dated December 2023.

[3] Hansen, D.J. "Federal Cell Facility Application Request for Information." via DRC-2023-003329 from the Utah Division of Waste Management and Radiation Control to Vern Rogers of EnergySolutions, April 24, 2023.

If you have further questions regarding the response to the director's request of DRC-2023-004939, please contact me at (801) 649-2000.

Sincerely,

Vern C. Rogers

Digitally signed by Vern C. Rogers
DN: cn=Vern C. Rogers, o=EnergySolutions, ou=Waste Management Division, email=vcrogers@energysolutions.com, c=US
Date: 2023.12.27 13:00:30 -07'00'

Vern C. Rogers
Director, Regulatory Affairs

enclosure

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Operational Period Modeling of Depleted Uranium Radionuclide Concentrations in Groundwater, Pond Water, Pond Biota, and Air, and Modeling of Radon Ground Surface Flux

Revision 2, December 2023

A screening calculation of potential radionuclide concentrations in the groundwater, surface water, biota, and air pathways is conducted for the Federal Cell Facility using the waste inventory and other applicable parameters from the Depleted Uranium (DU) PA v2.0. The modeling is performed using RESRAD-OFFSITE version 4.0. Parameter values are tabulated below. An operational period of 20 years is assumed[1].

The operational period model assumes that a groundwater well is located 90 ft from the edge of the contaminated zone, and applies DU PA model K_d values for silty sand (contaminated zone and vadose zone; Unit 3), silty clay (liner material and pond sediment; Unit 4), and clay (saturated zone; Unit 2) as well as DU model physical characteristics for the waste disposal layer and the vadose and saturated zones.

The RESRAD-OFFSITE model requires that the volume of the contaminated zone be constant. The operational period analysis incorporates the simplifying assumption that the time-averaged concentrations of disposed radionuclides in the contaminated zone during the emplacement period are one-half of the waste concentrations. Practically, this has the effect of protectively overestimating potential releases in the first half of the operating period.

The release of radionuclides from the disposed waste over time is protectively modeled as occurring immediately upon placement, such that functionally no “credit” is taken for the integrity of waste containers. In summary, the following protective assumptions are invoked:

1. the time-averaged disposed waste inventory for the Federal Cell is assumed to exist beginning at model year 0 (the beginning of disposal operations); and,
2. radionuclides are assumed to be freely available for environmental transport based on instantaneous equilibrium desorption from soil-like material, as defined by K_d values;

Because there are no natural surface water bodies in the vicinity of the site, Energy*Solutions’* permitted artificial evaporation pond constructed to store runoff water during active disposal operations is evaluated. A surface water evaporation pond with an area of 55,000 ft^2 and an average volume of 2.2 million gallons (Energy*Solutions* 2020 annual groundwater report values for the permitted 2000 Evaporation Pond (Energy*Solutions* 2021a)) is assumed to be the receiving medium for radionuclides transported with runoff from the Federal Cell during the operational period. Retained evaporation pond sediments will be disposed at the time of site closure. As noted above, all radionuclides are assumed to exist within a soil-like material and the surface erosion rate from the Federal Cell footprint to the evaporation pond is assumed to be 0.001 cm/yr, based on combined gully and sheet erosion modeling performed for the PA.

[1] RESRAD-Offsite was run for 50 years so results are available for longer operational periods, if desired. In this report, results are displayed to 25 years to facilitate evaluating trends, if any, beyond the assumed 20-year operational period.

Radionuclide concentrations in the open disposal cell were derived from the DU PA v2.0 GoldSim model. The initial inventory of each radionuclide in the disposal cell at the time of closure was assigned to the volume of the closed disposal cell (338,000 m^3), and was expressed as activity per unit mass using the dry bulk density of silty sand (Unit 3) and DU waste applied in the GoldSim model (1.609 g/cm^3). As described above, one-half of the as-disposed radionuclide concentrations were used in the RESRAD-OFFSITE modeling to represent average concentrations across the virtual 2.4-m thick zone of primary contamination. The derivation of the time-averaged radionuclide concentrations used in the RESRAD-OFFSITE modeling is shown in the table below.

Species	**Initial Inventory (Bq)**	**Initial Concentration (Bq/g)**	**Initial Concentration (pCi/g)**	**Time-Averaged Concentration (pCi/g)**
Sr-90	3.77E+10	1.79E-01	4.85E+00	**2.4**
Tc-99	1.93E+13	9.16E+01	2.48E+03	**1,238**
I-129	1.49E+10	7.10E-02	1.92E+00	**0.96**
Cs-137	9.71E+09	4.62E-02	1.25E+00	**0.62**
Ra-226	5.49E+12	2.61E+01	7.06E+02	**353**
U-233	9.17E+13	4.36E+02	1.18E+04	**5,890**
U-234	5.74E+14	2.73E+03	7.37E+04	**36,853**
U-235	5.15E+13	2.45E+02	6.61E+03	**3,307**
U-236	8.51E+13	4.05E+02	1.09E+04	**5,467**
U-238	4.71E+15	2.24E+04	6.06E+05	**302,819**
Np-237	4.56E+09	2.17E-02	5.86E-01	**0.29**
Pu-238	1.69E+08	8.01E-04	2.17E-02	**0.011**
Pu-239	1.03E+09	4.89E-03	1.32E-01	**0.066**
Pu-240	2.73E+08	1.30E-03	3.51E-02	**0.018**
Pu-241	3.24E+09	1.54E-02	4.17E-01	**0.21**
Am-241	1.14E+10	5.42E-02	1.46E+00	**0.73**

Modeling of transport to groundwater and a surface water retention pond was conducted for several open disposal cell geometries. The dimensions evaluated include:

a) a 100 × 100 ft area (30.48 m × 30.48 m [929 m^2]);

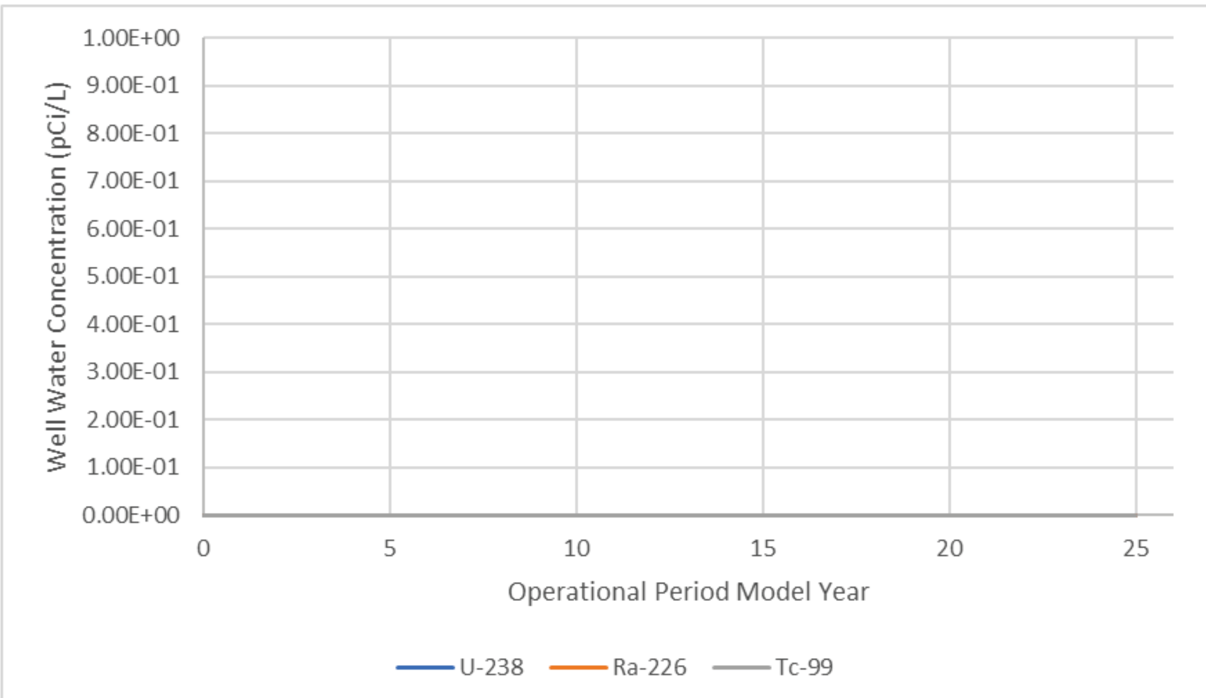
b) one-quarter of the disposal cell (133.5 m × 239.5 m [3.2E+04 m^2]);

c) one-half of the disposal cell (267 m × 239.5 m [6.4E+04 m^2]); and

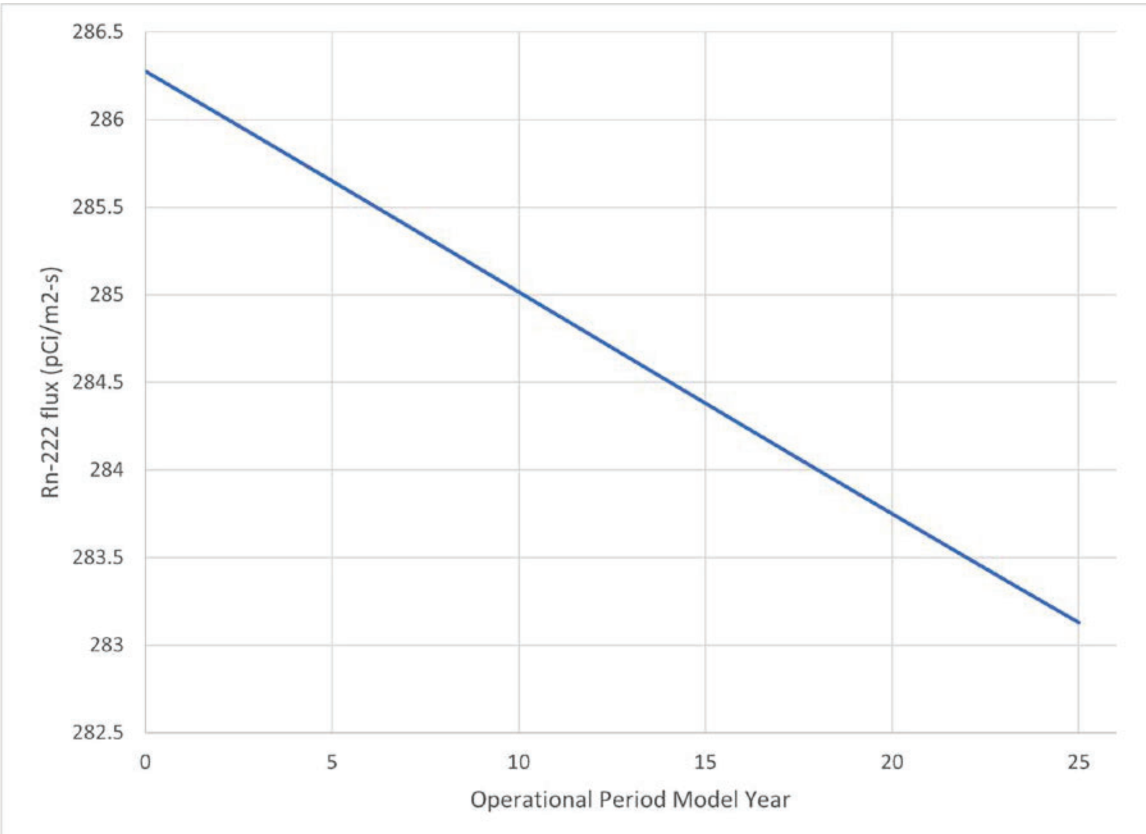
d) the entire footprint of the DU waste disposal cell (267 m × 479 m [1.3E+05 m^2]).

Model results were output at the following model years: 1, 5, 10, 15, 20, and 25 years. The assumed operational period is 20 years. Results are shown to 25 years to facilitate evaluating trends, if any, beyond year 20. Among the isotopes of uranium, results are shown for uranium-238. Because physical transport characteristics are identical for all the long-lived uranium isotopes, the other uranium isotopes would show identical characteristics with their modeled concentrations in various media proportional to their initial inventory. Based on initial inventory and transport characteristics, results are also shown for radium-226 (the parent of radon-222) and the highly soluble radionuclide technetium-99.

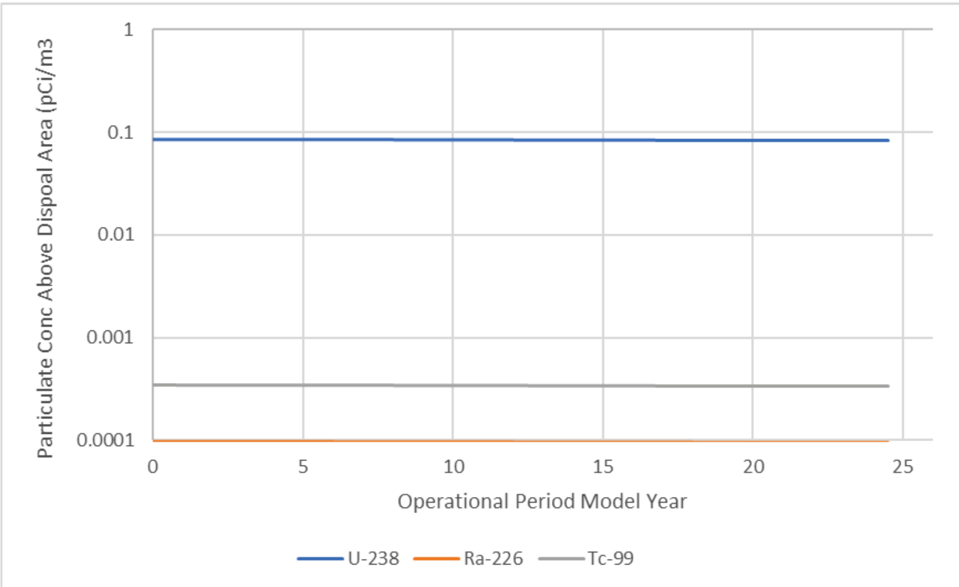
1. Well Water Radionuclide Concentrations. No breakthrough of any radionuclides at the well located 90 ft from the edge of the contaminated zone occurs within 25 years for any of the four open operational area cases evaluated. Even assuming no cover is placed on the disposed DU waste, and taking no credit for containerization, breakthrough of Tc-99 at the well does not occur until model year 200 in the RESRAD-OFFSITE evaluation. Longer-term modeling of releases to groundwater from the closed disposal cell is the subject of the DU PA.



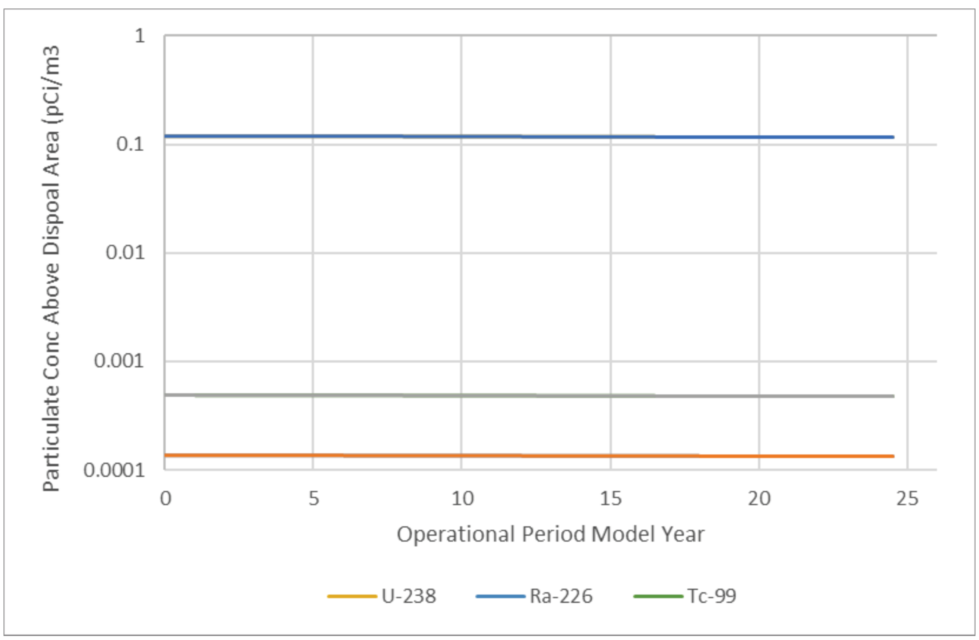
2. Radon Flux above Open DU Waste. Radon-222 flux above the open area of the disposal cell, based on decay of the Ra-226 parent, is independent of the assumed dimensions of the open portion of the disposal cell during operations. Modeled radon flux is based on the assumption that containers do not restrict release of radon gas, and the radium-226 source concentration in the DU waste is represented as a time-averaged concentration in a homogenous soil source of 2.4-m thickness. The initial ground surface flux of approximately 286 pCi/m^2-s decreases very slightly to about 283 pCi/m^2-s at model year 25. The rate at which radon-222 flux decreases is roughly proportional to the 1,600-year half-life of radium-226.



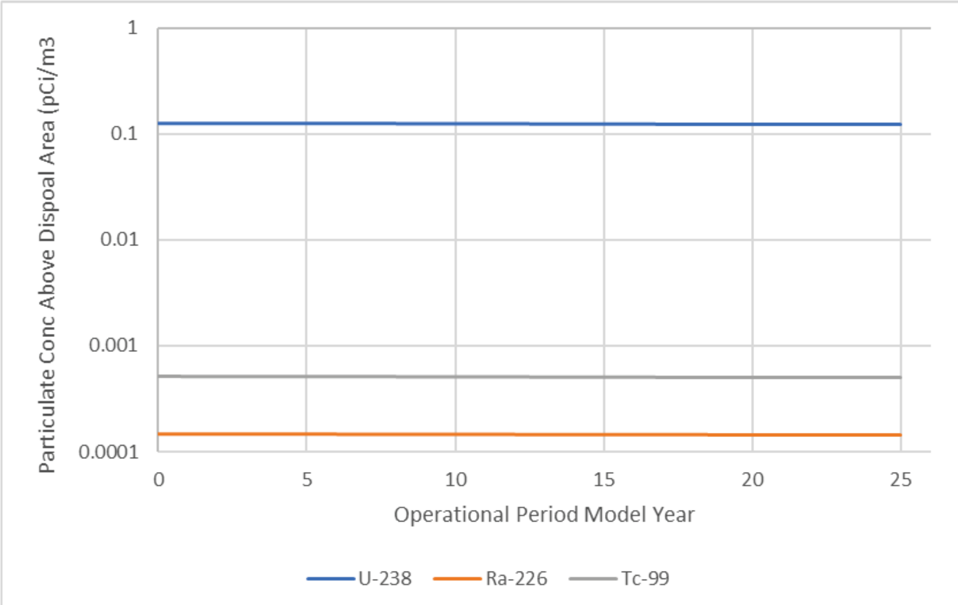
3. Concentrations of Particulate-Phase Radionuclides in Air above Open DU Waste. Concentrations of radionuclides above the assumed soil source term of the open disposal cell are modeled using default RESRAD-OFFSITE particulate resuspension and atmospheric mixing assumptions. Air concentrations are directly proportional to the virtual soil concentrations of these radionuclides, and these concentrations are essentially static across the modeling period. Although not evident on the scale of the plots, the radium-226 air particulates concentration decreases slightly over time in the same manner as radon-222 flux.



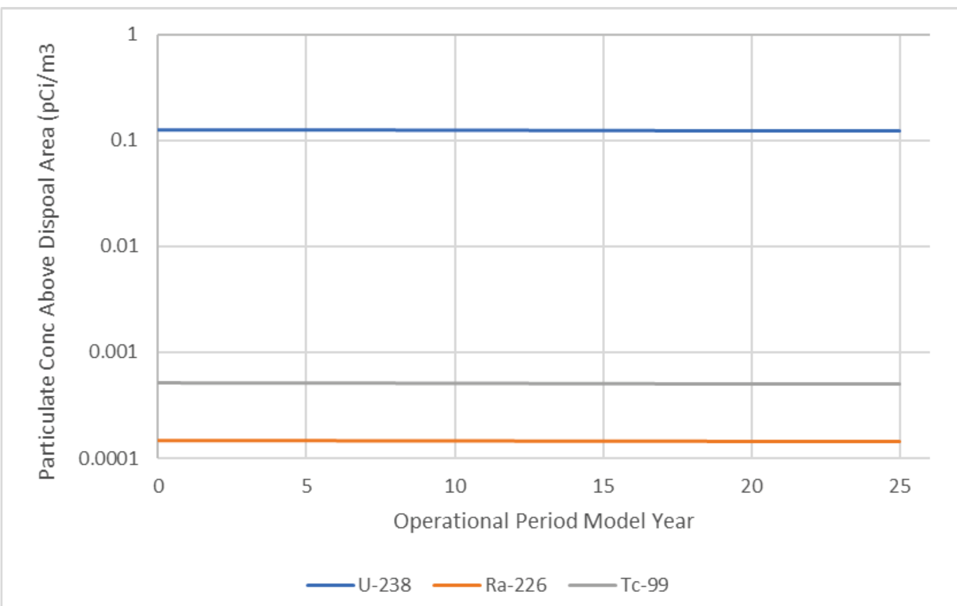
3a. Particulate Air Concentrations above a 929 m^2 Open Disposal Area



3b. Particulate Air Concentrations above a 3.2E+04 m^2 Open Disposal Area

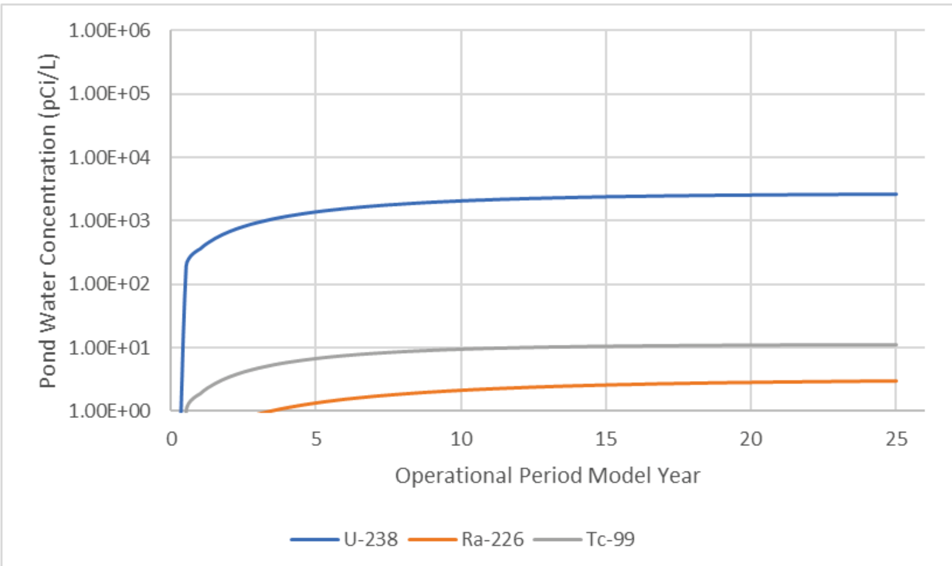


3c. Particulate Air Concentrations above a 6.4E+04 m^2 Open Disposal Area

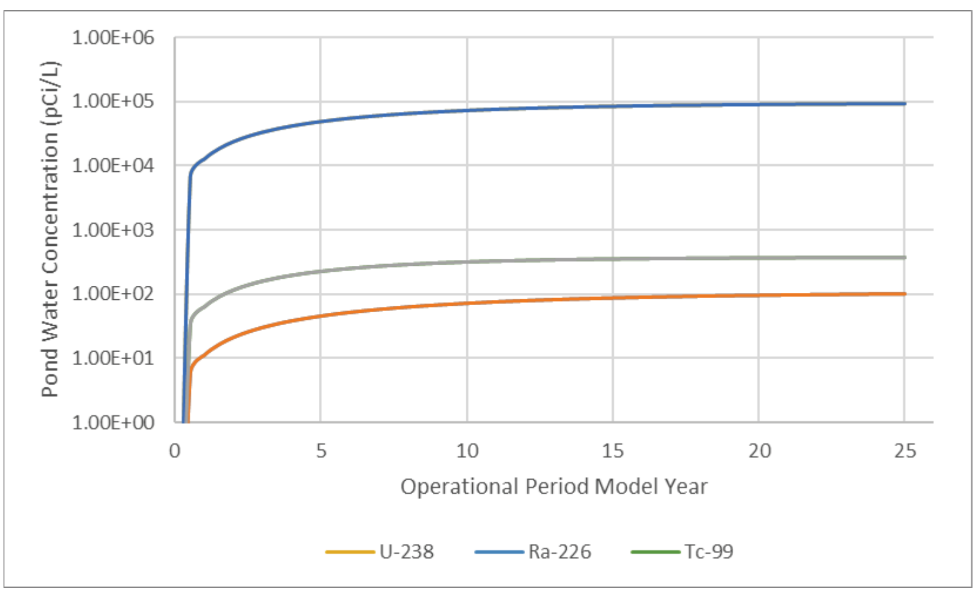


3d. Particulate Air Concentrations above a 1.3E+05 m^2 Open Disposal Area

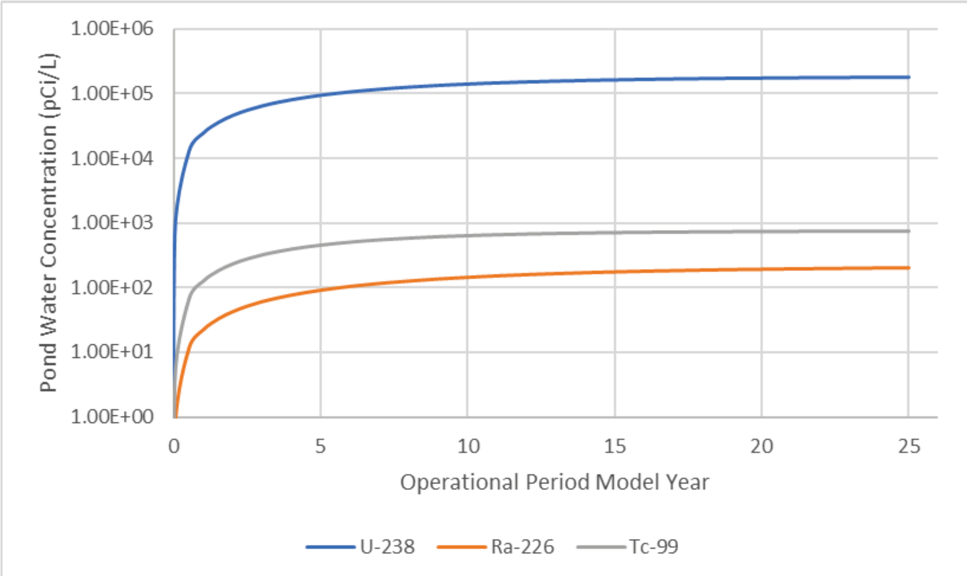
4. Concentrations of Radionuclides in Retention Pond Water. Radionuclide transport to the retention pond through erosion of the open disposal area by runoff and atmospheric deposition is tracked through modeled water concentrations, which are in equilibrium with pond sediments having an assumed active partitioning layer of 10-cm thickness. Pond water concentrations of radionuclides increase quickly and then begin to level off over time as incoming sediments eventually comprise all of the 10-cm mixing layer on the pond bottom. Technetium-99 reaches 90% of its pond water value at model year 25 by approximately year 12, and radium-226 pond concentrations reach 90% of their model year 25 value by model year 17. For uranium isotopes, 90% of peak pond water concentrations occur at approximately model year 14. Concentrations of radionuclides in pond water are directly proportional to the assumed size of the open operational area.



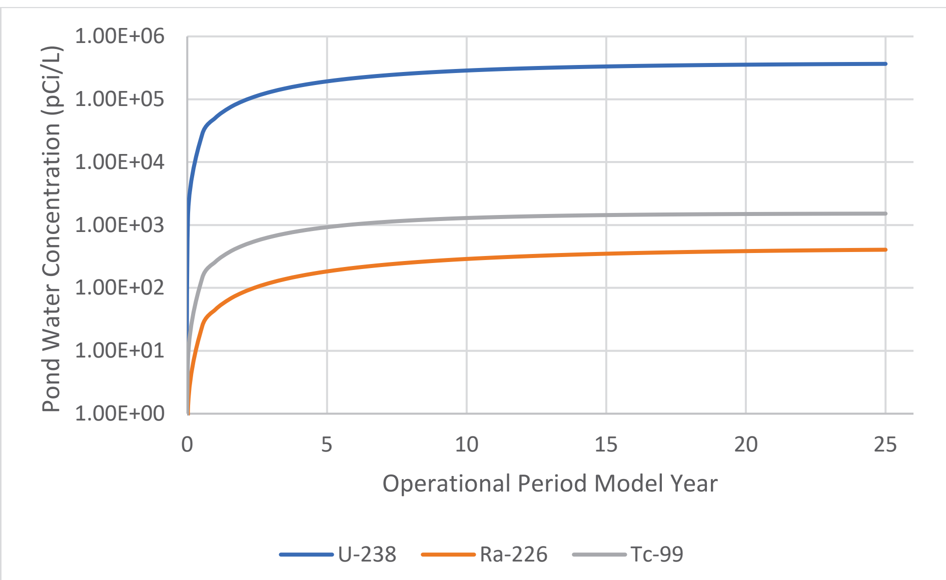
4a. Radionuclide Concentrations in Retention Pond Water for a 929 m^2 Open Disposal Area



4b. Radionuclide Concentrations in Retention Pond Water for a 3.2E+04 m^2 Open Disposal Area

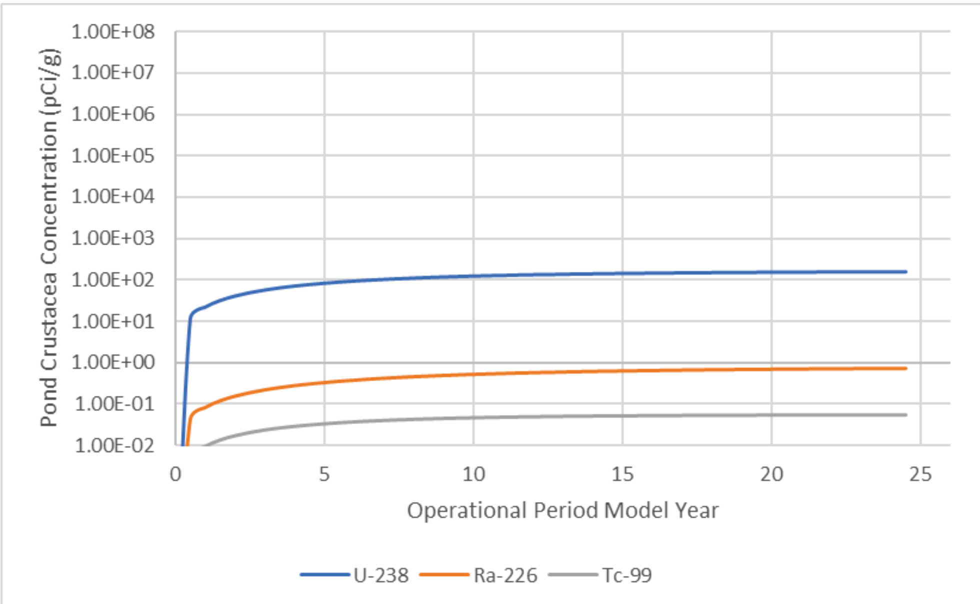


4c. Radionuclide Concentrations in Retention Pond Water for a 6.4E+04 m^2 Open Disposal Area

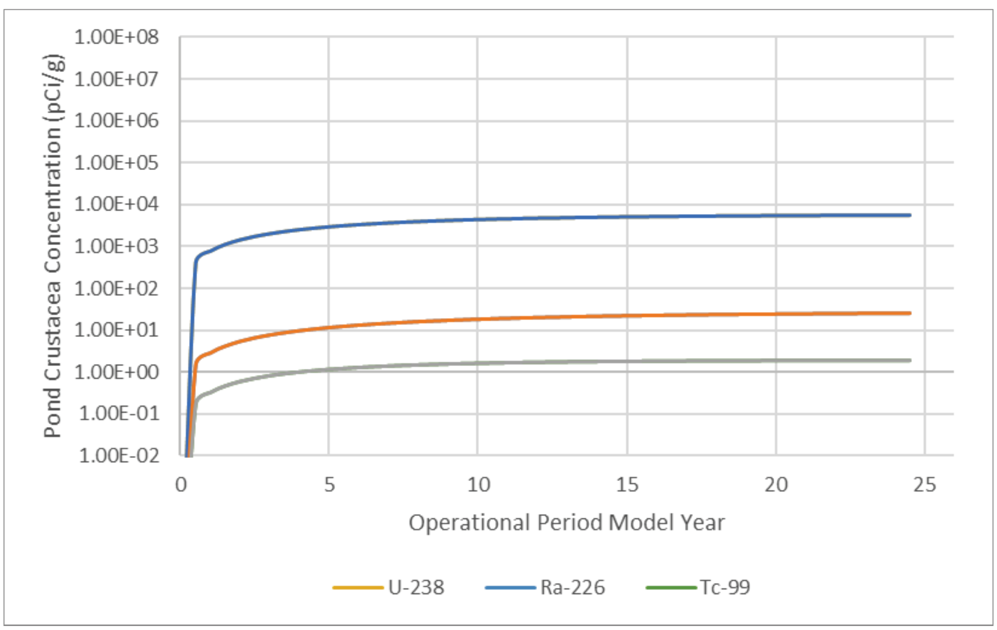


4d. Radionuclide Concentrations in Retention Pond Water for a 1.3E+05 m^2 Open Disposal Area

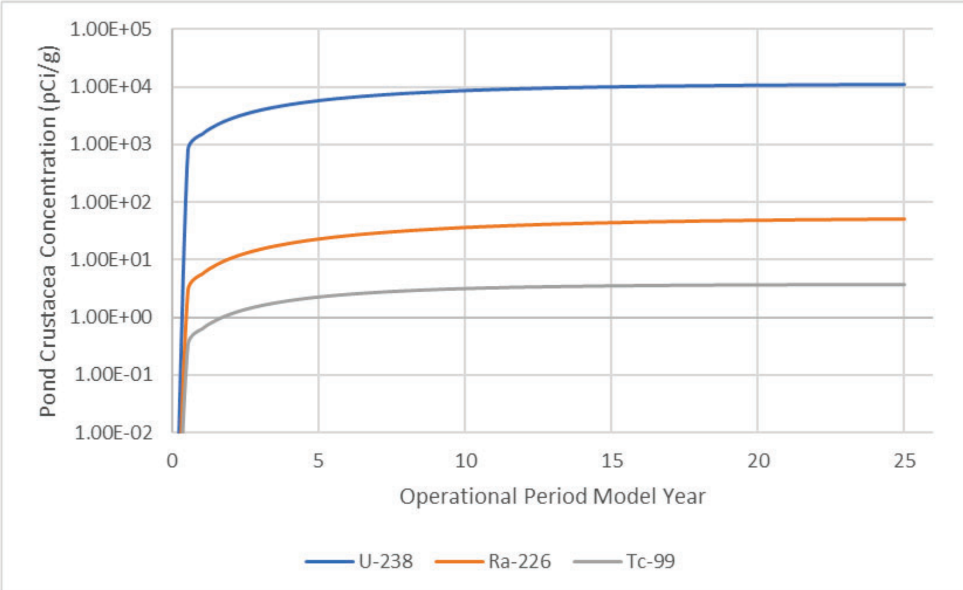
5. Concentrations of Radionuclides in Retention Pond Crustacea. RESRAD-OFFSITE includes modeling of radionuclide uptake into fish and crustacea inhabiting a surface water body. The stormwater retention body is assumed to host small invertebrates, which are represented by crustacea in the RESRAD-OFFSITE model. Crustacea tissue concentrations are modeled in RESRAD based on element-specific partitioning among three media: pond water, pond sediment, and crustacean tissue. Over the 25-year modeling period, modeled concentrations in pond crustacea (assuming any exist) follow a similar pattern to pond water. As with pond water, concentrations of radionuclides in the tissues of crustacea are directly proportional to the assumed size of the open operational area.



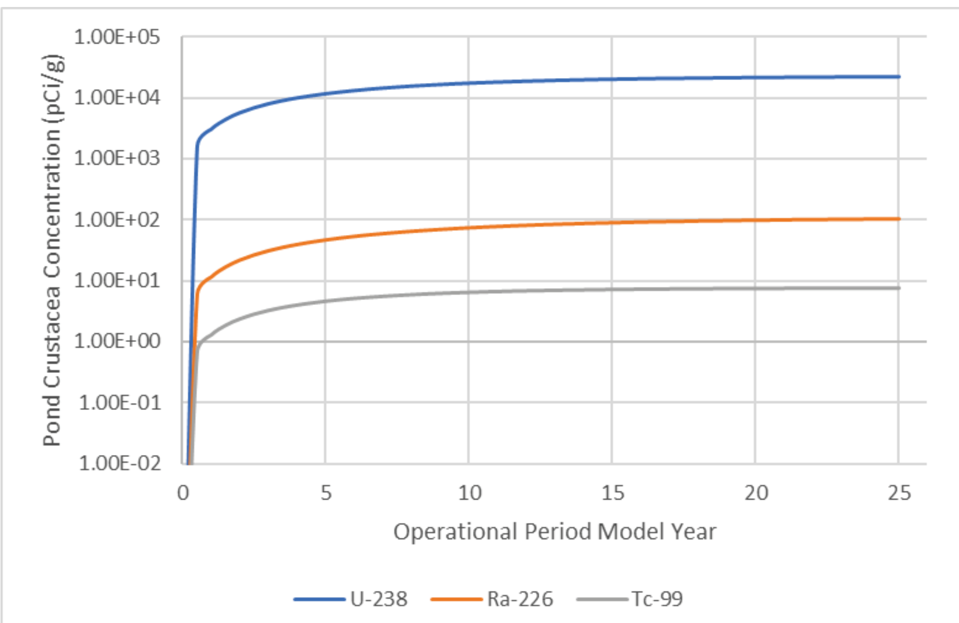
5a. Radionuclide Concentrations in Retention Pond Crustacea for a 929 m^2 Open Disposal Area



5b. Radionuclide Concentrations in Retention Pond Crustacea for a 3.2E+04 m^2 Open Disposal Area



5c. Radionuclide Concentrations in Retention Pond Crustacea for a 6.4E+04 m^2 Open Disposal Area



5d. Radionuclide Concentrations in Retention Pond Crustacea for a 1.3E+05 m^2 Open Disposal Area

RESRAD-OFFSITE v4.0 Clive Operational Period Model Parameter Values

Parameter Description	Units	Value	Reference	Notes
Preliminary Inputs				
Radionuclide release	–	–		Exponential release over time (proportional to inventory; RESRAD-ONSITE model) with first-order leach rates internally calculated using Clive DU PA Model v2.01 K_d values.
Number of unsaturated zones	unitless	3		A 1-ft unspecified clay liner, and 2-ft engineered liner, atop the native UZ
Active Exposure Pathways				
Set Pathways				Aquatic Foods, Drinking Water, and Radon activated to allow viewing of concentration graphs
Distribution Coefficients				
Contaminated Zone; Unsat Zone 2 (Unit 3)	ml/g			Deterministic values for Unit 3 (sand) taken from Clive DU PA Model v2.01.
Unsat Zone 1 and 2 (Unit 4)	ml/g			Deterministic values for silty clay taken from Clive DU PA Model v2.01.
Saturated Zone (Unit 2)	ml/g			Deterministic values for clay taken from Clive DU PA Model v2.01.
Suspended and bottom surface water body sediments	ml/g			Deterministic values for silty clay (Unit 4) taken from Clive DU PA Model v2.01.
Site Layout				
Bearing of x-axis (clockwise from N)	degrees	90	CAW Final Drawing 10014, C01, Rev. 2 (Energy*Solutions* 2021b)	Orientation of Class A West embankment is approximately in line with N-S axis.

Parameter Description	**Units**	**Value**	**Reference**	**Notes**
X and Y dimensions of primary contamination	m	267, 479		Entire DU cell area is assumed to be continuously open during operational period
X and Y dimensions of primary contamination	m	133.5, 239.5		One-half of DU cell area is assumed to be open during operational period
X and Y dimensions of primary contamination	m	66.75, 119.75		One-quarter of DU cell area is assumed to be open during operational period
X and Y dimensions of primary contamination	m	30.48, 30.48		A 100 by 100 ft DU cell area is assumed to be open during operational period
X,Y coordinates: fruit, grain, non-leafy and leafy vegetables, pasture, grain, dwelling	m			Not applicable. Only groundwater and surface water pathways are of interest.
X coordinates: surface water body (small, large)	m	400, 471.5		71.5-m length is the square root of the retention pond area of 55,000 ft^2 (5110 m^2); 400-m x-axis offset (133 m beyond primary contamination) is arbitrary and does not affect modeled pond conc's.
Y coordinates: surface water body (small, large)	m	0, 71.5		71.5-m length is the square root of the retention pond area of 55,000 ft^2 (5110 m^2).
Site Properties				
Precipitation	m/yr	0.2138		100-year daily records of precipitation generated by HELP; this is the mean value used in the PA model.
Rainfall and runoff factor	unitless	160	RESRAD default	A measure of the energy of the rainfall; used to calculate erosion rate and surface soil concentrations. (RESRAD-OFFSITE internally calculated erosion rate of 1.0E-05 m/yr defined to emulate the PA model.)

Parameter Description	Units	Value	Reference	Notes
Contaminated Zone Physical/Hydrological Parameters				
Length parallel to aquifer	m	267, 133.5, 66.75, 30.48		Assumed length of axis parallel to flow direction; values are for each of the four open operational areas evaluated.
Depth of soil mixing layer	m	0.15	RESRAD default	Negligible relative to 2.4-m thickness of the Contaminated Zone.
Deposition velocity of all particulates	m/s	0.001	RESRAD default	Used in RESRAD to model settling of particulates released to the atmosphere.
Irrigation	m/yr	0		No irrigation on a disposal cell is assumed.
Evapotranspiration coefficient	unitless	0.98		Set at minimum value such that, if the entire DU cell is open during operations, volumetric recharge rate through the CZ is not less than the GW flow rate beneath the CZ (a RESRAD requirement for the code to run).
Runoff coefficient	unitless	0.1		RESRAD v6 Manual (Yu et al. 2001), Table E.1; tight impervious clay. Contaminated zone runoff reflects the clay liner for the operational period.
Slope-length-steepness factor	unitless	0.4	RESRAD default	Accounts for the effect of terrain on erosion; used to calculate erosion rate and surface soil concentrations.
Cover and management factor	unitless	0.003	RESRAD default	Accounts for the effects of land use (forest, pasture), vegetation (type and height), and management practices (mulching, crop rotation) to calculate erosion rate and surface soil concentrations.
Support practice factor	unitless	1	RESRAD default	Accounts for conservation practices to manage erosion; used to calculate erosion rate and surface soil concentrations.
Thickness of contaminated zone	m	2.4		Clive DU PA Model v2.01

Parameter Description	Units	Value	Reference	Notes
Thickness of clean cover	m	0		
Soil erodibility factor of contaminated zone	ton/ac	0.349		Varied from RESRAD default of 0.4 to produce Clive DU PA model cover erosion rate of 1E-05 m/yr.
Total porosity of contaminated zone	unitless	0.393	Neptune 2021, mean of the distribution	The contaminated zone (CZ) is represented as a virtual soil source comprised of disposed DU waste and backfill. RESRAD default values, developed to be reasonably protective when actual parameter values are unspecified, are applied to the virtual source.
Effective porosity of contaminated zone	unitless	0.393	Neptune 2021, mean of the distribution	
Dry bulk density of contaminated zone	g/cm^3	1.609	Neptune 2021, mean of the distribution	
Contaminated zone field capacity	unitless	0.3	RESRAD default	
Contaminated zone b parameter	unitless	5.3	RESRAD default	
Contaminated zone hydraulic conductivity	m/yr	10	RESRAD default	
Contaminated zone longitudinal dispersivity	m	0.05	RESRAD default	
Fraction of eroded radionuclides deposited in the surface water body		1	RESRAD default	Consistent with site CSM for evaluating groundwater and surface water impacts.
Unsaturated Zone Hydrology				
Number of unsaturated zone strata	unitless	3		Zone 1 is the 1-ft clay liner, below which is a 2-ft engineered clay liner (Zone 2), and then the unsaturated zone (Zone 3) that is primarily Unit 3 materials.
Clay liner unsaturated zone thickness (Zone 1)	m	0.3048		Assumed 1-ft clay liner.
Clay liner unsaturated zone hydraulic conductivity (Zone 1)	m/yr	1		Assumed 3-fold higher permeability than engineered liner (Zone 2)
Clay liner unsaturated zone thickness (Zone 2)	m	0.6096		Assumed 2-ft engineered clay liner.

Parameter Description	Units	Value	Reference	Notes
Clay liner unsaturated zone hydraulic conductivity (Zone 2)	m/yr	0.315		Engineered liner has maximum design permeability of 1E-06 cm/s
Clay liners unsaturated zone b parameter (Zones 1 and 2)	unitless	11		RESRAD v6 Manual (Yu et al. 2001), Table E.2; clay.
Zone 3 unsaturated thickness	m	3.93		Calculated from CAS embankment measurements as the mean value of Zone 3 thickness. Mean Zone 3 thickness computed by interpolating data from the 4 corners of the embankment. Thickness at each corner calculated as the elevation of the bottom of the clay liner minus the water table elevation.
Zone 3 unsaturated dry bulk soil density	g/cm^3	1.61	Bingham Environmental (1991); Appendix B	Calculated as particle density × (1 - total porosity). A particle density of 2.65 g/cm3 was assumed based on the higher of values calculated by Colorado State University Porous Media Laboratory from two Unit 3 borehole cores.
Zone 3 unsaturated total porosity	unitless	0.393		Based on the saturated moisture content of Zone 3. Estimate calculated with Monte Carlo methods using data from two Unit 3 borehole cores.
Zone 3 unsaturated effective porosity	unitless	0.393		Effective and total porosity assumed to be identical.
Zone 3 unsaturated field capacity	unitless	0.232		Based on Unit 3 soil texture of 45% sand, 39% silt, and 15% clay (*Unsaturated Zone Modeling* (Neptune 2021)). Field capacity from Table 4 of Schroeder et al. (1994); HELP soil class 8 (loam).
Zone 3 unsaturated hydraulic conductivity	m/yr	227		Associated with silty loam soil texture (Yu et al. (2001); Table E.2).

Parameter Description	Units	Value	Reference	Notes
Zone 3 unsaturated b parameter	unitless	5.3	RESRAD default	Defines a relationship between soil hydraulic conductivity and moisture content. Default value is applicable to a sandy/silty soil type such as Unit 3.
Unsaturated zone longitudinal dispersivity (all unsaturated zones)	m	0.14		Higher values of longitudinal dispersivity result in shorter radionuclide transport times. Longitudinal dispersivity is a function of the length of the flow path (Gelhar et al. 1992). The ratio of dispersivity to unsaturated zone thickness for the RESRAD-OFFSITE default values is 0.025. This is less than a value of 0.036 based on linear regression of the data shown in Figure 1 of Gelhar et al. (1992). The higher ratio of 0.036 was protectively applied to calculate dispersivity as 0.036 × 3.93 m.
Saturated Zone Hydrology				
Thickness of the saturated zone	m	4.94	Envirocare (2000, 2004)	Calculated as the mean of a normal distribution from measurements at Wells GW-19B, GW-27D, GW-25, and GW-1.
Dry bulk density of saturated zone	g/cm^3	1.57	Whetstone Associates (2000); Section 7.1.2	
Saturated zone total porosity	unitless	0.29	Whetstone Associates (2000); Section 7.1.3	
Saturated zone effective porosity	unitless	0.29		Effective and total porosity assumed to be identical.
Saturated zone hydraulic conductivity	m/yr	237.5	Whetstone Associates (2011)	

Parameter Description	Units	Value	Reference	Notes
Saturated zone hydraulic gradient	unitless	0.001	Whetstone Associates (2011)	
Depth of aquifer contributing to well	m	4.94		Corresponds to the screened interval of the well. Assumed to be equal to the aquifer thickness.
Saturated zone longitudinal dispersivity	m	0.99		Higher values of longitudinal dispersivity result in shorter radionuclide transport times. Longitudinal dispersivity is a function of the length of the flow path (Gelhar et al. 1992). The ratio of dispersivity to groundwater flow path length (distance to the well) for the RESRAD default values is 0.030. This is less than a value of 0.036 based on linear regression of the data shown in Figure 1 of Gelhar et al. (1992). The higher ratio of 0.036 was protectively applied to calculate dispersivity as 0.036 × 27.4 m (90 ft).
Saturated zone horizontal lateral dispersivity	m	0.001		RESRAD default is 0.4; smaller values of lateral dispersivity are conservative because dilution in the aquifer is minimized.
Saturated zone vertical lateral dispersivity	m	0.001		RESRAD default is 0.02; smaller values of lateral dispersivity are conservative because dilution in the aquifer is minimized.
Water Use				
Human consumption rate	L/yr	730		2 L/day. UAC R317-6-2.
Number of humans consuming	unitless	2		RESRAD default is 4; lower water use corresponds to minimal required pumping rate and less dilution of contamination in well water (Yu et al. 2007).

Parameter Description	Units	Value	Reference	Notes
Use indoors of dwelling	L/day	100		RESRAD default is 225; lower water use corresponds to minimal required pumping rate and less dilution of contamination in well water (Yu et al. 2007).
Irrigation applied to fruit, grain, vegetables, pasture, livestock feed, and dwelling	m/yr			Not applicable. Pathways limited to groundwater and surface water.
Well pumping rate	m^3/yr	75		RESRAD default is 5100. Minimum water need calculated in RESRAD-OFFSITE is 74.5 m^3/yr. Smaller values minimize radionuclide dilution and are more protective.
Occupancy				
Fraction of time spent on primary contamination (outdoors)		1		Specified for evaluation of radon air concentrations.
Groundwater Transport				
Distance parallel to aquifer flow from downgradient edge of contamination to well	m	27.4		A 90-ft distance is defined in the license application.
Distance perpendicular to aquifer flow from center of contamination to well	m	0		The well is assumed to be located in the center of the groundwater flow path from the embankment.
Distance parallel to aquifer flow from downgradient edge of contamination to surface water body	m	–		Not relevant; no connectivity specified between aquifer and pond.
Distance perpendicular to aquifer flow from center of contamination to surface water body	m	–		Not relevant; no connectivity specified between aquifer and pond.
Convergence criterion	unitless	0.001	RESRAD default	RESRAD default is 0.001. Pertains to a tradeoff between accuracy of the numerical integration and computation time.
Number of saturated zone sub zones (to model dispersion of progeny)	unitless	1	RESRAD default	A single saturated zone is defined in the PA model.

Parameter Description	**Units**	**Value**	**Reference**	**Notes**
Number of partially saturated zone sub zones (to model dispersion of progeny)	unitless	1	RESRAD default	Not used, no partially saturated zones are defined.
Surface Water Body				
Volume of surface water body	m^3	8328	Energy*Solutions* 2020 annual groundwater report (Energy*Solutions* 2021a)	2.2 M gallons on July 2020
Potential evaporation	m/yr	0		Maintains constant water volume
Stream outflow as a fraction of total outflow		1		Internally calculated by RESRAD using inflow ratio
Thickness of sediment layer in partitioning equilibrium with water	m	0.1		Assumption
Size of catchment area	m^2	10,500		Internally calculated by RESRAD; x- and y-coordinates of catchment areas specified such that watershed has about twice the area of the pond.
Sediment delivery ratio		1		Internally calculated by RESRAD using size of catchment area.
Fraction of deposited radionuclides reaching surface water body		1		Deposited quantity of radionuclides reaching catchment protectively approximated by atmospheric release.

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