UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF RADIATION AND INDOOR AIR
WASHINGTON, D.C. 20460

September 27, 2024

Mr. Michael Gerle, Director
Environmental Regulatory Compliance Division
Carlsbad Field Office
U.S. Department of Energy
P.O. Box 3090
Carlsbad, New Mexico 88221-3090

Re: Seventh set of questions on the Replacement Panels Planned Change Request (RPPCR)

Dear Mr. Gerle:

The U.S. Environmental Protection Agency is continuing its review of the U.S. Department of Energy's submittal of the RPPCR. This letter transmits a set of agency technical questions on the updated brine reservoir model. The EPA would appreciate a timely response to these questions to help expedite its review. The Agency also suggests a follow-up call and/or technical exchange to discuss these questions.

If you have any questions concerning this request, please contact Jonathan Major at (202) 343-9891 or at Major.Jonathan@epa.gov.

Sincerely,

DANIEL SCHULTHEISZ

Digitally signed by DANIEL SCHULTHEISZ
Date: 2024.09.27 11:59:30 -04'00'

Tom Peake
Director
Center for Waste Management and Regulations

ENCLOSURE
1. Seventh set of technical questions on the RPPCR

cc: Anderson Ward, DOE CBFO
Justin Marble, DOE EM
Lee Veal, EPA

Ray Lee, EPA
Jonathan Major, EPA
Winifred Okoye, EPA
EPA Docket

Enclosure 1: Seventh set of technical questions on the RPPCR

Information requests for DOE related to the modified Castile Reservoir brine volume used in the RPPCR PA.

Summary

The RPPCR changed the maximum, upper bound volume of a hypothetical, pressurized brine reservoir in the Castile Formation. The technical basis for this proposal is documented in Gross and Gjerapic (2022), and its implementation in the RPPCR is described in a report by Docherty (2023). Encountering a Castile brine reservoir during future exploratory drilling at the WIPP site could result in the release of large volumes of pressurized brine into WIPP waste panels. Such an event is a principal driver for low probability but high consequence direct brine releases (DBRs) to the accessible environment in WIPP performance assessment (PA). EPA performed a technical review of the proposal, including comparing previously proposed and used models for the pressurized brine reservoir.

Gross and Gjerapic (2022) performed a re-analysis of Popielak et al.'s (1983) data from the WIPP-12 and ERDA-6 wells using a newer, two-domain model for fractured media developed by Karasaki (1987). As with the Popielak et al. model, Karasaki's analytical approach assumed a radially symmetric, confined aquifer with homogeneous properties for the near-field and far-field domains. Gross and Gjerapic (2022, p. 11) state that Karasaki's two-domain model represents an improvement over the approach used by Popielak et al. because it allows for evaluation of recorded pressure responses in terms of the permeabilities and compressibilities of the near-field and far-field reservoir domains, and allows for an improved evaluation of long-term reservoir releases. The long-term data are important because they provide the basis for estimating the ultimate areal extent of the reservoir and the maximum available pore volume. EPA considers the use of the model re-evaluating the maximum Castile reservoir brine volume to be a positive advance in WIPP PA modeling of physical processes. EPA also found the suggested implementation of reservoir volume in WIPP PA, as proposed by Docherty (2023), to be reasonable and appropriate. However, EPA noted some potential uncertainties in fitting the model to the well test data and seeks clarification on the implementation of the updated brine volume in the RPPCR PA.

Italicized text below provides introductions, further explanations, or backgrounds to the questions and comments. Questions and comments have been organized and grouped by section of the report and topic.

Requests related to brine volume estimates made using the two domain model

A summary of Castile reservoir brine volumes in Table 1 shows that both the maximum and minimum values have varied considerably through the years. Through several steps, Gross and Gjerapic (2022) adequately verified the use of Karasaki's (1987) two domain model for re-evaluating the maximum Castile reservoir brine volume's implementation in WIPP PA and calibrated it using the results of Popielak et al.'s (1983) WIPP-12 field tests. However, Gross and Gjerapic's (2022) sensitivity studies addressed only reservoir thickness and initial conditions. They omitted uncertainty in the equilibrium reservoir pressure and did not provide an explanation for the incomplete match with test results at the end of the long-term WIPP-12 shut-in Test #3 (see Figure 12 from Gross and Gjerapic, 2022). The Agency has the following questions.

Table 1. EPA Summary of various Castile Brine Reservoir volumes

Source	Minimum (m^3)	Maximum (m^3)
Popielak et al (1983)	2.7×10^5	1.4×10^7
DOE CCA PA (1996)	3.2×10^4	1.6×10^5
EPA PAVT (1998)	3.4×10^6	1.7×10^7
DOE CRA19 PA (2019)	4.0×10^6	2.0×10^7
Gross & Gjerapic (2022)	3.61×10^6	5.90×10^6
Docherty (2023)	1.18×10^6	5.90×10^6

RPPCR7-BrineRes-1: acceptance of calibration curves after ~400 hours

Please justify the acceptance of the calibrated curves in Figure 12 of Gross and Gjerapic (2022) when the field data after about 400 hours show a significantly different behavior.

> *The calibrated curves in Gross and Gjerapic's match to Popielak et al.'s (1983) WIPP long-term pressure buildup curve (see Gross and Gjerapic 2022, Figure 12) increasingly deviate from the measured field pressures beginning at a recovery time of about 400 hours. These field data appear to have been ignored except for the final pressure measurement of 162 psig. It is not clear why the calibrated curves were found to be acceptable in view of this large departure from the field data.*

RPPCR7-BrineRes-2: causes of field pressure peak and decline in long-term shut-in test

Please explain the probable cause or causes of the field pressure peak at about 170 psig, the subsequent decline to between 150 and 160 psig, and the rationale for apparently ignoring this higher pressure when estimating reservoir volume.

> *With reference to Figure 12, the field pressure peaks at about 170 psig after about 4,000 hours of recovery time and then declines without explanation and apparently before the effects of the gas cap were identified and the gas was vented. This decline suggests a*

possible leak developing in the wellbore or perhaps at the wellhead that could have affected pressures measured after the gas cap was vented. A peak recovery pressure of 170 psig would be indicative of a much larger brine reservoir.

RPPCR7-BrineRes-3: uncertainties and the 162 psig as final reservoir equilibrium pressure

Popielak et al.'s (1983) adoption of 162 psig as the final reservoir equilibrium pressure does not appear to adequately account for uncertainty. Please justify use of this value by Gross and Gjerapic (2022) in calculating maximum reservoir brine volume without considering multiple sources of uncertainty that could provide a reasonable basis for higher equilibrium pressures and larger reservoir brine volumes.

Popielak et al.'s (1983, p. H-53) identification of 162 psig as the final equilibrium shut-in pressure for the WIPP-12 brine reservoir occurred at a time when several disruptive events were occurring that potentially affected the pressure measurements and increased their uncertainty.

- *As illustrated in Gross and Gjerapic (2022, Figures 12 and 13), the wellhead pressure had been declining for about 1500 hours from a peak of 170 psig to a low of between 150 and 160 psig when a gas cap formed that abruptly increased the wellhead pressure to 175 psig in about 960 hours (40 days). When the gas was vented, the pressure dropped to ~142 psig and then quickly stabilized at 162 psig for about 380 hours (16 days) when another gas cap started to form. Given the pressure oscillations occurring before and after the 16-day stabilization period, the uncertainty in assuming that 162 psig represented long-term equilibrium conditions should be evaluated.*
- *After the gas cap was vented, the wellhead pressure apparently stabilized for about 16 days (about 380 hours) until another gas cap began to develop. Considering the asymptotic nature of approaches to stability in such systems, were 380 hours enough to strongly support a conclusion that equilibrium pressure had been reached in a test that lasted over 7,000 hours?*
- *As illustrated in Gross and Gjerapic (2022, Figures 12 and 13), the deviation of pressure data from the calibrated two-domain model curves, the peaking at 170 psig at about 4,000 hours, and the subsequent decline to between 150 and 160 psig over the next ~1500 hours adds additional uncertainty if unexplained. All of this occurred before the gas cap was vented. Did a leak develop in the system? Would 170 psig be a better estimate of the equilibrium pressure?*
- *Ambient temperature variations were reported by Popielak et al. (1983, p. H-14) that caused the wellhead pressure readings to fluctuate, but they considered this effect to have been largely eliminated by insulating the wellhead.*
- *According to Popielak et al. (1983, p. H-14), leaks into the Salado from the uncased, open WIPP-12 borehole could have lowered the buildup pressure by approximately 6 to 7 psi over the long duration buildup period. In considering the importance of anchoring the maximum reservoir volume at a value that is unlikely to be reasonably exceeded, this observation alone would increase the*

reasonably maximum equilibrium reservoir pressure to 169 psig. EPA considers that this and the other uncertainties described above indicate that an equilibrium pressure of 162 psig may be too low.

- *Popielak et al. (1983) express some uncertainty in the adoption of 162 psig as the reservoir equilibrium pressure, stating in support of this adoption on p. H-53 that "After more than nine months of recovery, the WIPP-12 reservoir should be near equilibration."*
- *As an example of the sensitivity of reservoir volume to equilibrium pressure, according to Gross and Gjerapic's (2022) Figure 12, increasing the equilibrium pressure by about 5 psig (from 162 to 167 psig) appears to increase the maximum reservoir radius from 3,675 m to 5,000 m. Assuming the same porosity, an increase of 5 psig could increase the maximum reservoir brine volume by a factor of $5000^2/3675^2 = 1.85$. This would increase the estimated maximum brine volume from 5.90×10^6 m^3 to 1.09×10^7 m^3, which is approaching EPA's PAVT maximum volume of 1.7×10^7 m^3.*

RPPCR7-BrineRes-4: basis for estimate of maximum brine reservoir pore volume

Please justify basing the estimate of the maximum brine reservoir pore volume in Gross and Gjerapic (2022, p. 31) on Popielak et al.'s (1983, p. G-47) average porosity range of 0.4 to 0.7 percent rather than on their total porosity range of 0.1 to 1.0 percent.

> *Gross and Gjerapic (2022, p. 31) calculated the range of far field brine reservoir pore volumes using Popielak et al.'s (1983, p. G-47) representative average porosity range of 0.4 to 0.7 percent rather than the total porosity range of 0.1 to 1.0 percent that Popielak et al. used in their own estimate of maximum and minimum brine volumes (see Popielak et al. 1983, Figure H-19). EPA calculates that using Popielak et al.'s limiting maximum porosity of 1.0 percent instead of their average maximum porosity of 0.7 percent would have increased the estimated maximum reservoir brine volume by 39 percent to 8.2×10^6 m^3. Although not directly sampled in WIPP PA, the reservoir porosity effectively has a triangular distribution because if its close association with Castile bulk rock compressibility. Such a distribution was selected in part because the maximum and minimum values can be identified with a reasonable confidence that the true value lies within those bounds. Popielak et al. identified those bounding porosity limits as ranging from 0.1 to 1.0 percent and referred to the porosity range of 0.4 to 0.7 percent as average rather than limiting values. Given that Gross and Gjerapic (2022, p. i) are proposing a new maximum brine volume, it is not clear why they choose Popielak et al.'s average porosity range rather than their limiting porosity range.*

Requests related to the implementation of the modified brine reservoir model in the RPPCR PA:

The Agency found the implementation of reservoir volume in WIPP PA, as proposed by Docherty (2023), to be reasonable and appropriate. Increasing the volume of the cells representing the brine reservoir in BRAGFLO allowed more realistic values of reservoir porosity to be incorporated into WIPP PA and also allowed direct calculation of Castile pore compressibility consistent with other reservoir parameters. When possible, performance should be assessed using models that simulate actual physical processes and conditions.

Docherty's analysis showed that the change in maximum brine volume proposed by Gross and Gjerapic (2022) and its implementation in PA had relatively little impact on WIPP repository performance. The change slightly reduced total releases. This lack of substantial impact was to be expected because the mean total brine flow up the intrusion borehole was calculated to be on the order of 40,000 m^3, which is only a small fraction (about 1%) of the reservoir volume (Docherty 2023, Figure 8). Brine releases are sufficiently small and reservoir brine volumes are sufficiently large that releases are not expected to be significantly constrained by any reasonable estimate of reservoir volume.

The Agency has, however, questions for DOE related to the implementation of the modified reservoir in WIPP PA.

RPPCR7-BrineRes-5: further description and explanation of revised geometric representation of Castile brine reservoir in BRAGFLO

Please describe the conceptual model, mathematical model, and parameters involved in calculating flow from the reservoir to the intruding borehole, including the impacts on the results stemming from the revised geometric representation of the Castile brine reservoir in BRAGFLO.

> *Changes in the cross-section areas of the BRAGFLO cells representing the brine reservoir and increases in the distance from the borehole to the outer edge of the reservoir may place additional constraints on flow from the reservoir to the borehole.*

RPPCR7-BrineRes-6: difference in BRAGFLO grid representation between Docherty (2023) and RPPCR PA (DOE, 2024)

Please explain the differences between the extended representation of the Castile brine reservoir in the RPPCR PA BRAGFLO grid (DOE 2024, Figure 3-1) and the extended representation in the BRAGFLO grid studied by Docherty (2023, Figure 2), including any changes in the calculated reservoir properties resulting from these differences, and explain how these differences affect or do not affect the conclusions in Docherty (2023).

> *Docherty (2023) is provided as a source reference in DOE (2024, Section 2.8.1) to support the extended representation of the Castile brine reservoir in the RPPCR PA BRAGFLO grid (DOE 2024, Figure 3-1), yet that representation is different from the representation in*

the BRAGFLO grid supporting Docherty's analysis (see Docherty 2023, Figure 2). For example, the RPPCR representation extended over 48 grid columns (columns 13 through 60) while the representation in Docherty extended over 51 grid columns (columns 9 through 59). Although the calculated reservoir properties are sensitive to reservoir geometry, no discussion was provided to explain whether the revised RPPCR grid resulted in changes to the more realistic set of reservoir properties achieved by the Docherty (2023) grid, whether the characteristics of brine flow from the reservoir to the borehole were affected, and whether the impact analyses conducted by Docherty are still relevant.

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