Savannah River Remediation
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INTEROFFICE MEMORANDUM

SRR-CWDA-2021-00057
Revision 0

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SUBJECT: Selected PORFLOW Modeling Configurations to Support RSI-4 Analysis

This memorandum documents a handful of key decisions associated with PORFLOW modeling configurations for supporting RSI-4 analyses.

RSI-4 is a Request for Supplemental Information (RSI) from the U.S. Nuclear Regulatory Commission (NRC), wherein the NRC requested:

> "an analysis that: (1) provides risk insight into the effects of additional and coupled saltstone degradation mechanisms; (2) uses a more realistic arithmetic average for degraded and intact saltstone; and (3) is consistent with the response to RSI-1, RSI-2, and RSI-3 regarding uncertainty in flow through the closure cap and engineered barriers above the disposal structures. It would be useful if that analysis would include the volumetric flow rates, as shown in Figure 7.1.1 of the PA, for key materials (e.g., saltstone, roof, walls, joints, fast flow paths)." (ML20254A003)

An uncertainty analysis has been prepared which evaluated the uncertainties associated with the long-term hydraulic degradation of saltstone (SRR-CWDA-2021-00056). While this uncertainty analysis is still in draft and is currently under technical review, it is not expected that any of the major conclusions will change.

Additionally, a small number of scoping runs had been performed in PORFLOW to develop insights needed to inform additional modeling decisions.

This memorandum provides recommendations for PORFLOW modeling based on the aforementioned information. The modeling recommendations discussed herein are changes relative to the PORFLOW modeling described in the Saltstone Disposal Facility (SDF) Performance Assessment (PA) (SRR-CWDA-2019-00001); any modeling configurations or inputs not discussed herein are to be modeled the same as the Compliance Case of the SDF PA.

SDU Selection: SDU 9

For evaluating the various uncertainties associated with RSI-4, it is recommended to use Vadose Zone Flow Modeling for Saltstone Disposal Unit (SDU) 9 rather than running models for every SDU. Using only a single SDU should reduce model run-times.

SDU 9 was selected because it is a 375-foot Diameter SDU. These larger SDUs are assigned more inventory than any of the other SDU designs (see Section 3.3 of the SDF PA), which means that there is more potential risk associated with them. Of the 375-foot Diameter SDUs, SDUs 6, 7, and 11 are considered lower risk than SDUs 8, 9, 10, and 12 based on their locations within the SDF, proximity to the 100-meter SDF boundary, and predominant directions of ground water flow (see Section 4.4.8 of the SDF PA). Having down selected the SDUs to SDUs 8, 9, 10 and 12, SDU 9 was selected because in the SDF PA it is assumed to be constructed closer to the water table than the other SDUs (see Section 4.4.4.3 of the SDF PA). Being closer to the water table, releases from SDU 9 have been shown to dominate the model results within the 1,000-year Compliance Period and for a significant portion of the 10,000-year Performance Period (see Sections 5.5 and 5.7 of the SDF PA).

Species Selection: Cl-36, I-129, and Tc-99

Dose results in the SDF PA are dominated by contributions from I-129 and Tc-99 (see Sections 5.5, 5.7, and 5.8 of the SDF PA). The next highest dose contributor was Cl-36, but it is generally order of magnitude lower than I-129 and Tc-99. For the RSI-4 analyses, the scope may be limited to only these three radionuclides.

Scoping Runs in PORFLOW

In preparation of RSI-4, a number of additional scoping runs were developed in PORFLOW to aid in making decisions associated with potential modeling configurations. These scoping runs are summarized in Table 1 and discussed further below.

Table 1. Summary of Scoping Runs

Case ID	Infiltration	HDPE/GCL Degradation	Silting-In
CaseCV	SDF PA	SDF PA	SDF PA
CaseSA06	SDF PA	SDF PA	Bottom-Up
CaseSA15	SDF PA	SDF PA	Uniform
CaseSA09	SDF PA	Instant at 1975	SDF PA
CaseSA10	SDF PA	Instant at 1975	Bottom-Up
CaseSA13	SDF PA	Instant at 600	SDF PA
CaseSA17	SDF PA	Instant at 600	Uniform
CaseSA07	RSI-New	SDF PA	SDF PA
CaseSA08	RSI-New	SDF PA	Bottom-Up
CaseSA16	RSI-New	SDF PA	Uniform
CaseSA11	RSI-New	Instant at 1975	SDF PA
CaseSA12	RSI-New	Instant at 1975	Bottom-Up
CaseSA14	RSI-New	Instant at 600	SDF PA
CaseSA18	RSI-New	Instant at 600	Uniform

Notes: Cell shading in the Case ID column matches the colors of the curves in Figures 1, 2, and 3. Shading in the configuration columns indicate changes relative to the SDF PA Compliance Case Model. Cases SA01 through SA05 were developed for another task and are not included in this memorandum. Cases SA06 through SA18 are arranged based on the model configuration settings.

These scoping runs were limited to Vadose Zone Flow and Vadose Zone Transport from SDU 9, and only Cl-36, I-129, and Tc-99 were used. These scoping runs evaluated three configuration options: Infiltration, High Density Polyethylene/Geosynthetic Clay Liner (HDPE/GCL) Degradation, and Silting-In.

Configuration Options for the Scoping Runs

For the **Infiltration Option**, two configurations were used: SDF PA and RSI-New. The "SDF PA" option uses the same infiltration rates as the Compliance Case from the SDF PA (see Table 4.4-5 of the SDF PA). The "RSI-New" option uses the recommended Compliance Infiltration from Appendix D of SRR-CWDA-2021-00040. These two options may be thought of as representing low infiltration conditions (SDF PA) or high infiltration conditions (RSI-New).

For the **HDPE/GCL Degradation Option**, three configurations were used: SDF PA, Instant at 1975 (years), and Instant at 600 (years). These options are applied to all HDPE and HDPE/GCL layers in the SDU 9 Vadose Zone Flow Model, including at the SDU roof and between the SDU mud mats. The "SDF PA" option uses the same HDPE/GCL degradation model as the Compliance Case from the SDF PA (see Section 4.4.2.7 and Figures 4.4-19 and -20 of the SDF PA). Using the SDF PA approach, the HDPE degrades to backfill (with a saturated hydraulic conductivity of 4.1E-05 cm/s) while the GCL remains unchanged (with a saturated hydraulic conductivity of 5.0E-09 cm/s). Because the GCL is thicker than the HDPE, the blended saturated hydraulic conductivity of the degraded material is 1.3E-09 cm/s. The "Instant at 1975" option maintains initial conditions for the HDPE/GCL materials until 1975 years after closure, at which point the material is assumed to degrade instantly to the blended saturated hydraulic conductivity of the degraded material of 1.3E-09 cm/s. The year 1975 was selected as the expected service life for the HDPE from the SDF PA. Finally, for the "Instant at 600" configuration option, the HDPE/GCL materials retain the initial conditions until 600 years after closure, then the saturated hydraulic conductivity of the degraded material is assumed to be 4.62E-05 cm/s (this is maximum GCL value from SRR-CWDA-2021-00033, Table 9.3-6). The year 600 was selected because it is about midway between the Mean (648 years) and the Median (558 years) service life estimates from SRR-CWDA-2021-00033, Table 9.2-6.

For the **Silting-In Option**, three configurations were used: SDF PA, Bottom-Up, and Uniform. The "SDF PA" option uses the same assumption as in the SDF PA, which is the assumption that the lower lateral drainage layer (LLDL) (i.e., the sand layer above the SDUs) will retain initial properties indefinitely. For the Bottom-Up option, it is assumed that the fines or clays from the overlying backfill will gradually migrate into the LLDL and settle in low areas of the LLDL; it also assumes an end-state equal to backfill, thus the saturated hydraulic conductivity of the LLDL gradually reduces (in layers) the from 5.0E-02 cm/s to 4.1E-05 cm/s, with low areas transitioning first and higher areas transitioning last. For the Uniform option, it is assumed that the fines or clays from the overlying backfill will gradually migrate into the LLDL and settle uniformly throughout the LLDL; it also assumes an end-state that is somewhere between sand and backfill, with a saturated hydraulic conductivity of 3.0E-05 cm/s, thus the saturated hydraulic conductivity of the

LLDL gradually reduces (homogenously) the from 5.0E-02 cm/s to 3.0E-05 cm/s. This transition was developed based on the minimum values from Table 6.2-1 of SRR-CWDA-2021-00031.

Scoping Run Flux Results

The SDU 9 flux results (for Cl-36, I-129, and Tc-99) from each of the scoping run cases were plotted (See Figures 1, 2, and 3). These results are discussed below.

Figure 1. Cl-36 Fluxes to the Water Table from Selected Scoping Runs

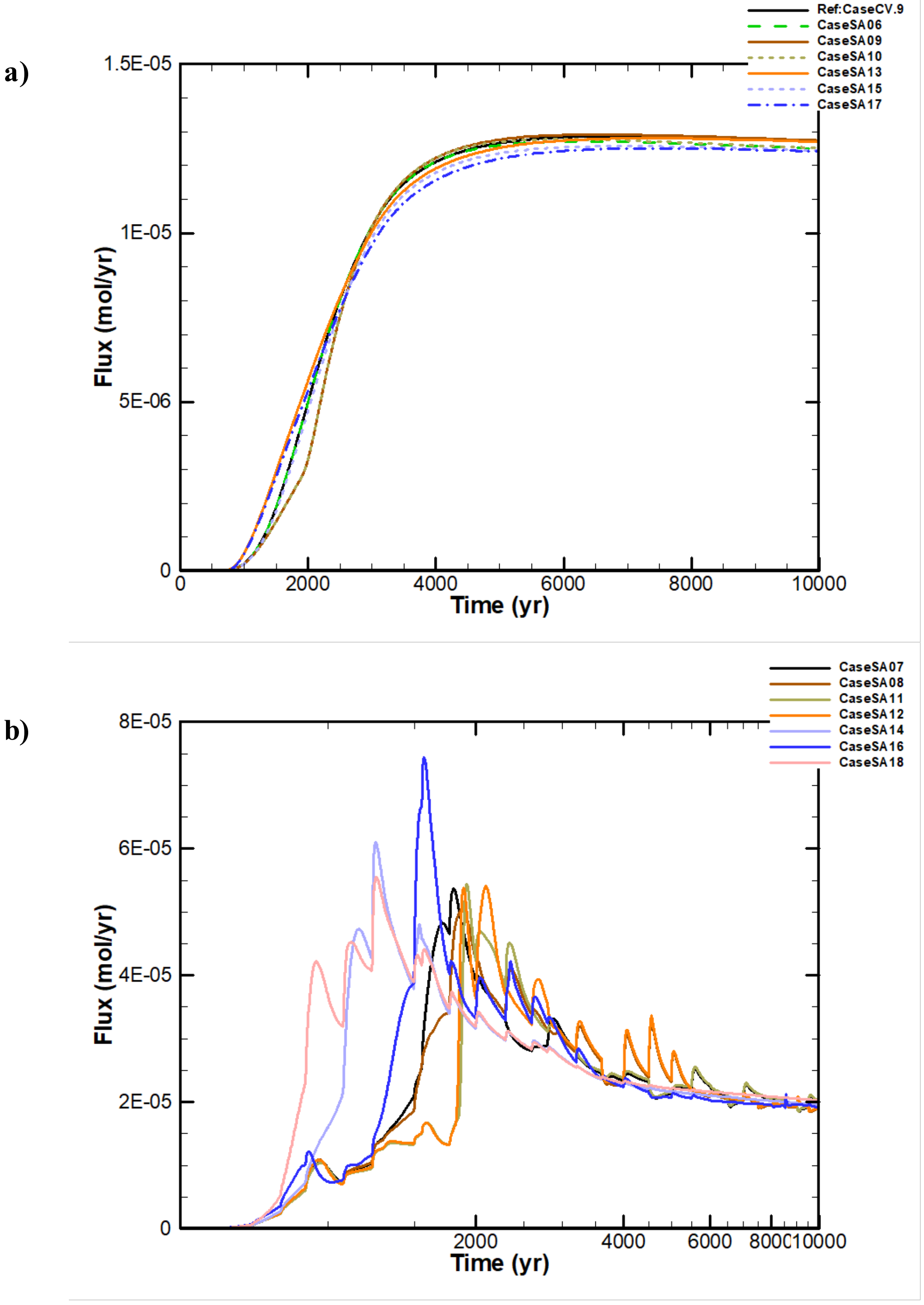


Figure 2. I-129 Fluxes to the Water Table from Selected Scoping Runs

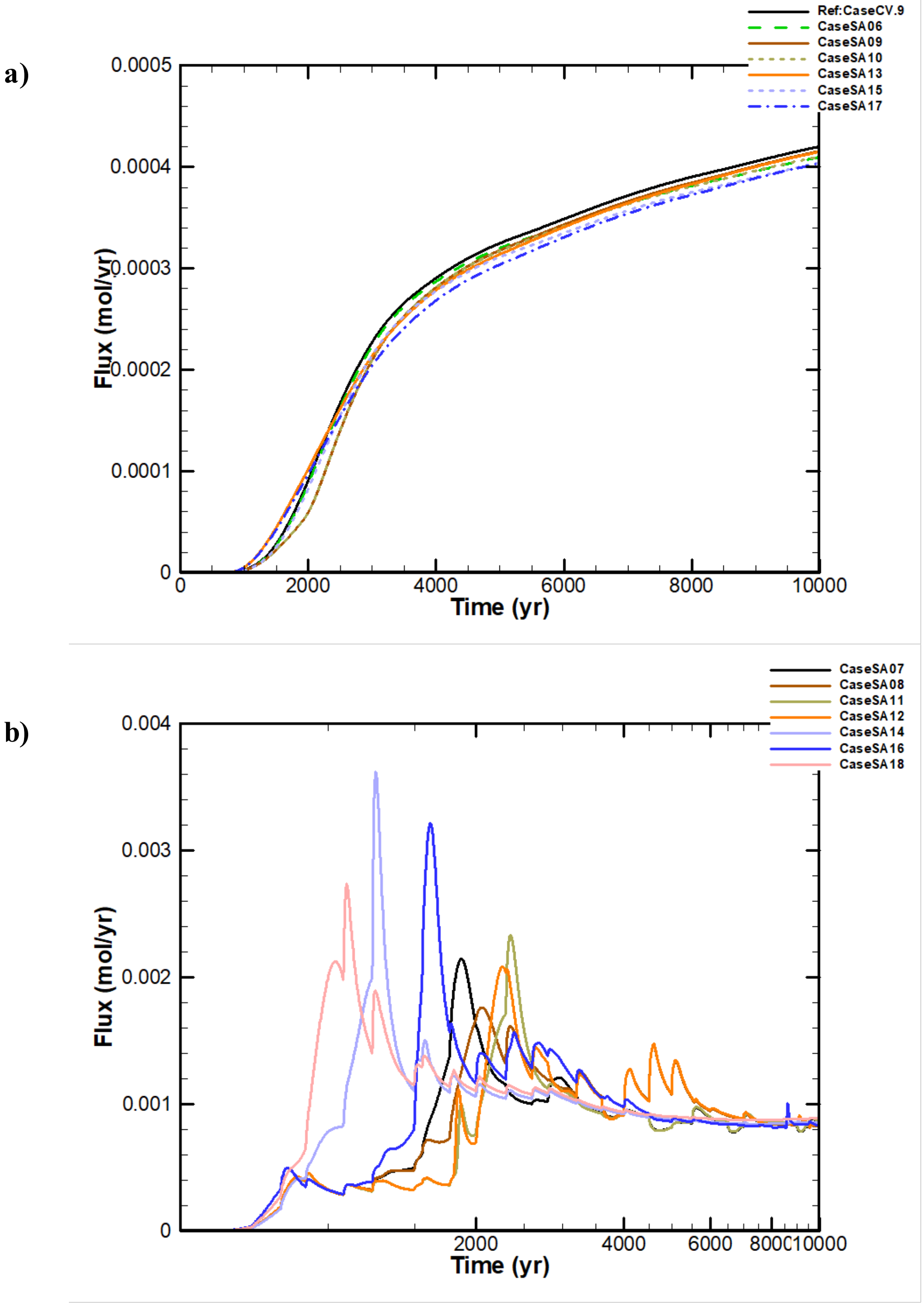
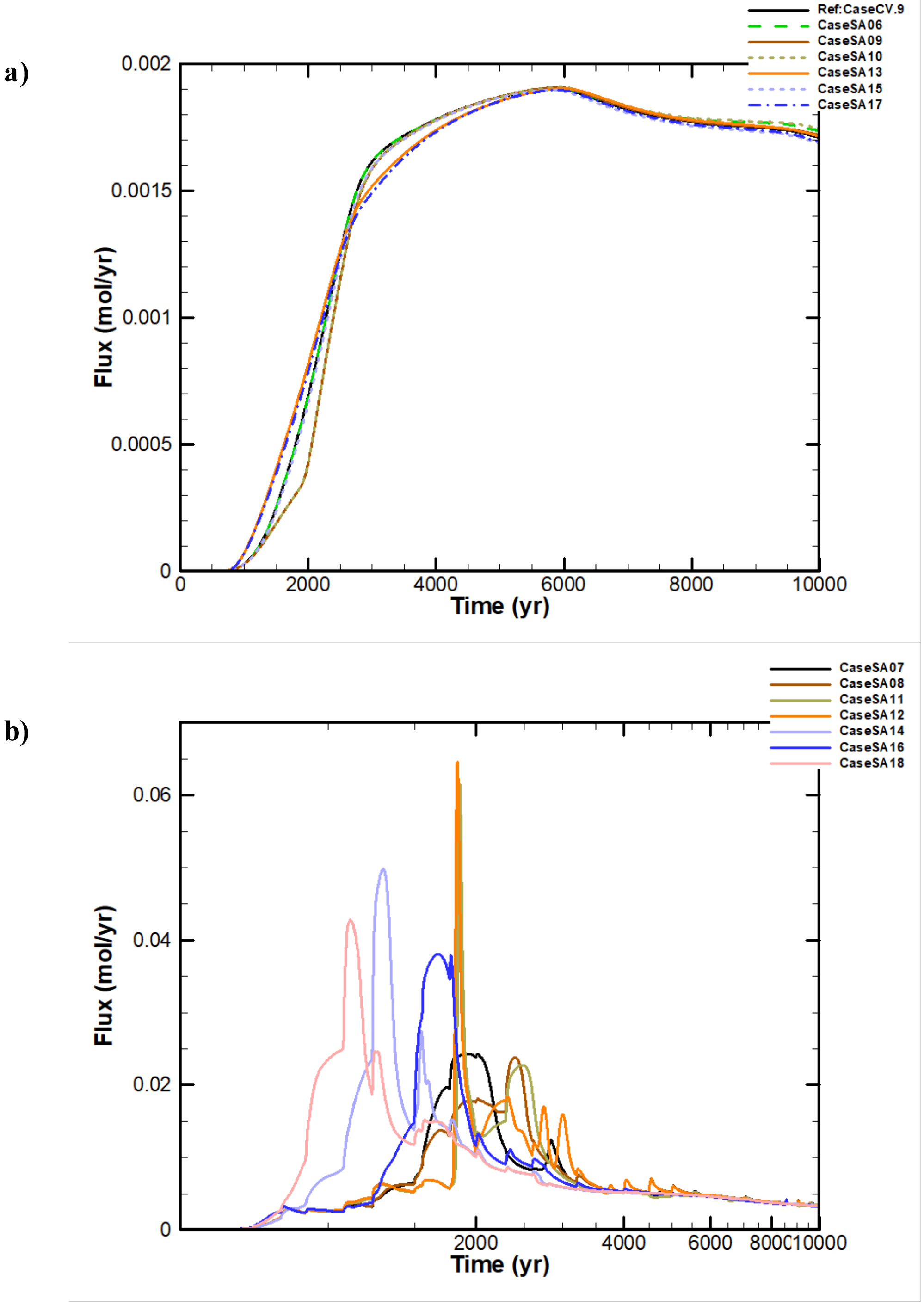


Figure 3. Tc-99 Fluxes to the Water Table from Selected Scoping Runs



Evaluation of Scoping Run Fluxes

Infiltration Options

For Figures 1, 2, and 3, the top panel (a) shows fluxes for the scoping runs using the lower (SDF PA) infiltration rates, whereas the bottom panel (b) shows fluxes for the scoping runs using the higher (RAI-New) infiltration rates. The first observation is that in the cases with the lower infiltration rates, there was virtually no change to the fluxes regardless of which configuration options were applies. Therefore, these top panel figures are not discussed any further, and only the bottom panel figures are used to inform decisions related to RSI-4 modeling.

Next, by comparing the magnitudes of the fluxes from each of scoping runs against the equivalent fluxes from the SDF PA Compliance Case results (CaseCV.9), a qualitative assessment of the potential risks associated with these fluxes may be summarized as:

- In Figure 1, the peak Cl-36 fluxes from CaseCV.9 were on the order of 1.3E-05 mol/yr, while the peak Cl-36 fluxes from the higher infiltration scoping runs were on the order of 5.0E-05 to 7.5E-05 mol/yr (or an increase of less than a **factor of five**).
- In Figure 2, the peak I-129 fluxes from CaseCV.9 were on the order of 4.2E-04 mol/yr, while the peak I-129 fluxes from the higher infiltration scoping runs were on the order of 1.6E-03 to 3.4E-03 mol/yr (or a maximum increase of approximately **factor of eight**).
- In Figure 3, the peak Tc-99 fluxes from CaseCV.9 were on the order of 1.8E-03 mol/yr, while the peak Tc-99 fluxes from the higher infiltration scoping runs were on the order of 2.2E-02 to 6.2E-02 mol/yr (or a maximum increase of more than a **factor of 30**).

Because the Compliance Case (i.e., CaseCV.9) results in the SDF PA show that dose contributions from I-129 and Tc-99 were similar in magnitude, and because the increases in fluxes were greatest for Tc-99, the increases in the Tc-99 fluxes represent the greatest risk of potential dose increase for the options under consideration in these scoping runs. Accordingly, modeling decisions associated with the configuration options shall be based on the observations of the Tc-99 fluxes (Figure 3). Since the focus is on configurations under the higher flow conditions, and because CaseSA07 is identical to the Compliance Case (except that the higher infiltration rate was applied), CaseSA07 provides the best basis for further comparisons.

HDPE-GCL Degradation Options

CaseSA14 (light blue curve in Figure 3(b)) is identical to CaseSA07 (black curve in Figure 3(b)), except CaseSA11 (olive curve in Figure 3(b)) applied the “Instant at 1975” option for the HDPE/GCL degradation. Similarly, CaseSA14 (light blue curve in Figure 3(b)) is also identical to CaseSA07 except CaseSA14 applied the “Instant at 600” option for the HDPE/GCL degradation. Comparing the fluxes from these cases, it is clear that the instantaneous degradation of the HDPE/GCL can result in significantly higher peak fluxes. From these observations, it is recommended that the HDPE/GCL degradation configuration that assumes instantaneous degradation (as opposed to the gradual approach applied in the SDF PA) be pursued further for RSI analyses.

Silting-In Options

Compared to CaseSA07 (black curve in Figure 3(b)), CaseSA08 (brown curve in Figure 3(b)) is the only case with lower fluxes. Per Table 1, CaseSA08 is a case that assumed the Bottom-Up Silting-In configuration for the LLDL. This suggests that Bottom-Up Silting-In may reduce fluxes. The other scoping run in Figure 3(b) with the Bottom-Up Silting-In configuration was CaseSA12 (orange curve in Figure 3(b)). Comparing this result to the flux from CaseSA11 (olive curve in Figure 3(b)) (wherein both of these cases applied the "Instant at 1975" option for the HDPE/GCL degradation), both of these cases had nearly identical peaks. This indicates that under this condition, the fluxes are less sensitive to the Bottom-Up Silting-In option. From these observations, it is recommended that the Bottom-Up Silting-In option not be pursued any further for RSI analyses.

Compared to CaseSA07 (black curve in Figure 3(b)), CaseSA16 (blue curve in Figure 3(b)) is identical except that it assumed the Uniform Silting-In configuration (see Table 1). The flux from CaseSA16 is both higher and earlier than CaseSA07, suggesting that Uniform Silting-In may increase fluxes. The other scoping run in Figure 3(b) with the Uniform Silting-In configuration was CaseSA18 (pink curve in Figure 3(b)). Comparing this result to the flux from CaseSA14 (light blue curve in Figure 3(b)) (wherein both of these cases applied the "Instant at 600" option for the HDPE/GCL degradation), CaseSA18 has a peak that was slightly lower than but also earlier than the peak flux from CaseSA14. This indicates that Uniform Silting will result in earlier fluxes and might increase the magnitude of those fluxes. From these observations, it is recommended that the Uniform Silting-In option be pursued further for RSI analyses.

Summary of Configuration Options Based on Scoping Runs

PORFLOW modeling performed in support of further RSI analyses should:

- Include the higher infiltration rates based on the infiltration uncertainty analyses described in SRR-CWDA-2021-00040,
- Apply instantaneous degradation of the HDPE/GCL, and
- Apply a silting-in configuration that assumes uniform degradation of the LLDL.

Time Intervals (TI) for Vadose Zone Flow Modeling

Although Vadose Zone Flow Modeling for the SDF PA examined flow conditions out to 100,000 years after SDF closure (see Section 4.4.4.4 of the SDF PA), for the purposes of RSI-4 evaluations, it is recommended to limit the scope of modeling to the 10,000-year Performance Period. This is period of time that is 10 times longer than the Compliance Period, so it is adequate for capturing potential long-term risks. This changes the number of Time Intervals (TIs) from 65 to 38. Additional efficiencies may be realized by further reducing the number of TIs during the 10,000-year performance period.

Use of Saltstone Degradation Uncertainties from SRR-CWDA-2021-00056

As previously mentioned, the uncertainties associated with the long-term hydraulic degradation of saltstone have been evaluated (SRR-CWDA-2021-00056). This evaluation describes a probabilistic model that was designed to generate much of the information requested by the NRC (per ML20254A003). Outputs from this probabilistic model may be used as inputs for PORFLOW.

These outputs include (but are not limited to):

- the *p*-averaging term used to estimate material properties for partially degraded saltstone,
- the time it takes for decalcification to fully degrade saltstone,
- an initial degradation fraction,
- the time and magnitude of potential seismic events,
- the service life (or assumed failure time) for the HDPE, and
- randomly sampled saturated hydraulic conductivities for initial saltstone and backfill.

Additional Considerations

Section 7.3.1 of the Quality Assurance report for the SDF PA explained that:

> "For the floors, because these are assumed to be more influenced by the underlying "native soil" (or natural vadose zone soil) rather than the backfill (due to the surface area interfaces), it was assumed the floors would degrade to 9.1E-05 cm/sec. Consistent with this approach, the mud mats should also have been degraded to 9.1E-05 cm/sec; however, instead these were degraded them to the value for backfill (4.1E-05 cm/sec)." (SRR-CWDA-2018-00068)

For PORFLOW modeling in support of the RSI analyses, this error will be corrected: the SDU floors *and* the SDU mud mats will be assumed to degrade to an end state that is hydraulically in equilibrium with the vadose zone.

PORFLOW model results should include fluxes to the water table for direct comparisons to the SDU 9 fluxes from the Compliance Case. Results should also include any information needed to estimate water balance results in support of responding to RSI-6 (Complete Water Budgets) (ML20254A003).

Additional PORFLOW modeling may also be required to address questions related to RSI-5 (Moisture Characteristic Curves).

References

ML20254A003, Koenick, S. S., *Preliminary Review of the U.S. Department of Energy's Submittal of the 2020 Savannah River Site Saltstone Disposal Facility Performance Assessment*, U.S. Nuclear Regulatory Commission, Washington DC, October 2020.

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