April 2, 2012

MEMORANDUM TO: Christepher McKenney, Chief
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FROM: David W. Esh, Senior Systems Performance Analyst **/RA/**
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SUBJECT: REVIEW OF STAFF RELEASE RATE CALCULATIONS FOR SALTSTONE

Enclosed please find my review of the staff release rate calculations used for development of the 2012 Technical Evaluation Report of the Saltstone disposal facility. I reviewed the spreadsheets provided by the staff (A. Ridge and K. Pinkston), performed independent calculations, and modified the spreadsheets provided by the staff. Overall I did not find any errors in the calculations in Excel spreadsheets, though I do note a couple of improvements that could be made. The results are sufficient for their purpose, which was for the staff to provide an independent assessment of the U.S. Department of Energy (DOE) performance assessment. The spreadsheet was user friendly and well-described with comments.

Conceptually, there are some caveats the staff should consider when describing their calculations:

1.) The staff results for larger fracture spacings (1m and larger) are likely to be conservative. I believe this to be the case because of the way inventory is tracked in the different sized blocks as the calculation progresses. Also, diffusional release is neglected.

2.) The differences in release rates for different cases likely do not correspond directly into the same magnitude change in dose, which was assumed. It is a rough approximation. This is because the unsaturated zone and far-field transport acts to smooth or disperse peaks in release from the source term.

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3.) The limiting case may not be any of the cases evaluated by the staff or DOE. The limiting case may be characterized by a wasteform that oxidizes and degrades but for which very limited water is available for release for some time (e.g. due to performance of an engineered cover). Then if the water flow rates increase rather discretely, such as due to failure of a geomembrane, the peak release rates are achieved. It may be appropriate to caveat the staff's analysis that the results are conditional on the temporal behavior of other parts of the system outside of the wasteform.

I performed independent analysis using a modified GoldSim model that was previously developed to review DOE's analysis of the Saltstone disposal facility in 2005 (D. Esh, A. Ridge, M. Thaggard – 2006). My analysis agreed reasonably well for the most conservative case (Case K), but had some divergence at higher fracture spacings where my results were lower than the staff's results.

Docket No.: PROJ0734

Enclosure:
Review of Staff Release Rate Calculations

cc: N. Devaser
A. Ridge
K. Pinkston

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REVIEW OF STAFF RELEASE RATE CALCULATIONS FOR SALTSTONE DISPOSAL FACILITY

Summary:

The U.S. Nuclear Regulatory Commission (NRC) staff (A. Ridge and K. Pinkston) developed spreadsheets to estimate the fractional release rates (and corresponding doses) from the Saltstone disposal facility as part of their review of U.S. Department of Energy's (DOE's) performance assessment. The spreadsheets reviewed were:

single_dual_extra_time_steps.xlsx	(received 2/24/12)
final fracture calc_new timestep_v2.xlsx	(received 2/28/12)
fracture summary_new timestep.xlsx	(received 2/28/12)

The purpose of these spreadsheets is to estimate the number of fractures present as a function of time for different fracturing models, estimate the corresponding amount of oxidation for each of the fracture models, and then estimate the temporal response of the Fractional Release Rate (FRR) of Tc for user-specified conditions.

1) All calculations appear to be correct numerically.

2) Some data differences between the spreadsheets were noted. Though they are minor they should be cleaned up when the final spreadsheets are archived.

Porosity -	0.58 vs. 0.60
Bulk density -	1.01 vs. 1.02 g/cm^3
K_d Red -	500 vs. 139 ml/g

3) The constant flow rate of 5E10 L/yr is extremely high. Though it doesn't matter from a calculation standpoint, it could be misinterpreted if the spreadsheets were to be distributed outside of NRC. I would recommend setting the value at somewhere around 5E6 L/yr which I think would be consistent with a long-term unperturbed infiltration rate.

4) The PORFLOW flow rates appear to be very optimistic based on the research performed by Craig Benson on analogous systems. The research suggests it is very difficult to attain flow rates that are a small fraction of expected natural infiltration rates for more than years to tens of years let alone thousands of years. It is understood that DOE's engineered cover has not been built yet, but at some point the high-level of performance reflected in DOE's performance assessment will need to be demonstrated. Otherwise the flow calculations are correct.

5) The fraction oxidized for different cases (fracture spacing, etc.) is consistent in both magnitude and timing for what I estimated independently using a GoldSim model. The GoldSim model is described in D. Esh, A. Ridge, M. Thaggard [2006]. The only modifications that were made were to change the data to be consistent with that used in the spreadsheets and to modify the fracture spacing (which was constant in the original

model) to be time-dependent. The time-dependency was implemented with a look-up table so that the exact response generated in the spreadsheets could be used. The GoldSim model was implemented probabilistically though so some parameters did differ from the spreadsheet which is a deterministic calculation. Of note the infiltration rate was set to a uniform distribution of 10 to 30 cm/yr and the Kd's for both oxidizing and reducing conditions were assigned long-normal distributions with the geometric means set to the values used by the staff in the spreadsheets.

Table 1 provides a comparison of the spreadsheet values and GoldSim values of FRR for select cases. The GoldSim model is conceptually different in a couple of important ways. First, there can be a delay period where the waste oxidizes, degrades, or both but there is very little release from the wasteform. This is due to an institutional control period and performance of an engineered cover. In the table comparisons, the engineered cover performance was eliminated but an institutional control period of 100 years was used. This can make a difference in the release rates at larger fracture spacing. At high fracture spacing, the FRR is driven by the highest rate of change in the fracture spacing which equates to a change in surface area. The GoldSim calculation had reasonable agreement with the spreadsheet. Second, the GoldSim calculation includes diffusion between regions (oxidized, degraded, intact) and the soil outside the vaults. Therefore an apples-to-apples comparison was not possible without substantial effort which was not warranted in this review effort. It should be noted that these are complex calculations that can vary over many orders of magnitude so agreement within an order of magnitude is quite reasonable. Conceptually the staff result at 1.0 m fracture spacing does not make complete sense to me. As the spacing increases an order of magnitude I would expect the drop in the FRR to be larger, and for it to drop in a non-linear manner.

Table 1 Comparison of Spreadsheet and GoldSim Model Estimated FRR's

Case	Tc FRR - spreadsheet	Tc FRR - GoldSim	Time of peak (yr) - spreadsheet	Time of peak (yr) - GoldSim
Log to 0.1, Case K	5.1E-4	2.5E-4	9700	8800
Log to 1.0, Case K	1.9E-4	7E-5* (3E-6)	13800	150 (10000)

* Peak occurs at much earlier time because of initial release of oxidized material following the institutional control period.

I also investigated the influence of time-stepping. The use of non-uniform time-stepping in the spreadsheet is a potential source of error. While the cumulative release rate curves are smooth, the fractional release rate curves are not. Figure 1 shows the results in the spreadsheet for a select case compared to a new calculation using a uniform 50 year time step. The error magnitude is on the order of 10%, which is not significant in this context but should be cleaned up if time permits and prior to archiving regardless.

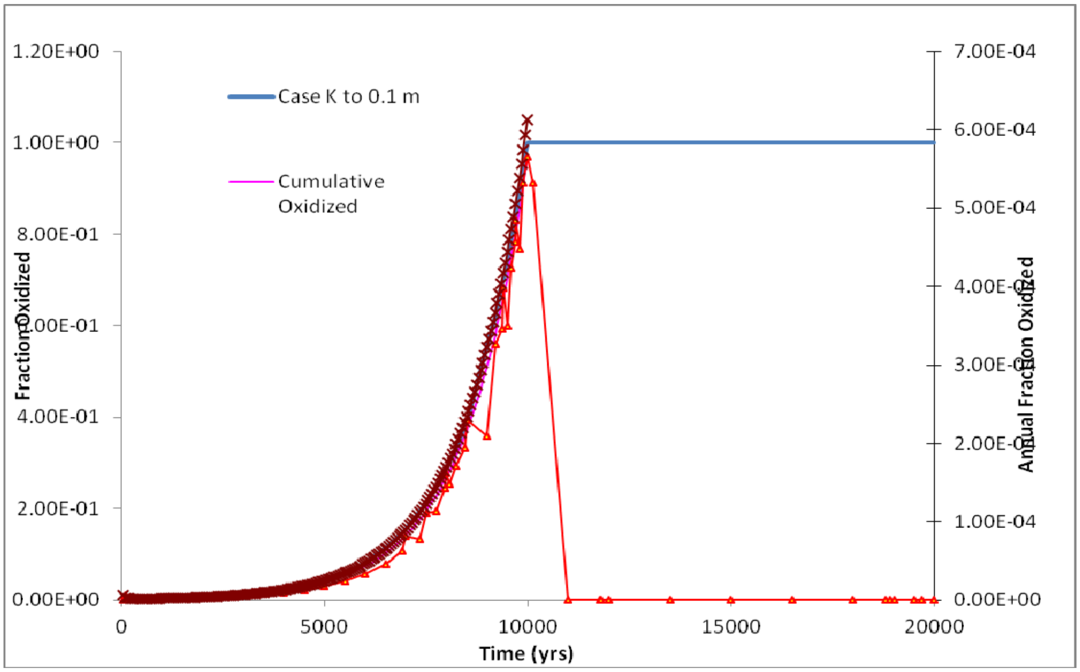

Figure 1 – The Impact of Using non-Uniform Time-Stepping in the Staff Spreadsheet. Red curve is staff non-uniform time-stepping annual fraction oxidized. Maroon is uniform 50-yr time-stepping.

Reference

David W. Esh, A. C. Ridge, M. Thaggard, “Development of Risk Insights for Regulatory Review of a Near-Surface Disposal Facility for Radioactive Waste”, Waste Management 2006, Tucson, Arizona, February 26 - March 2, 2006.