UTAH DIVISION OF RADIATION CONTROL
ENERGY*SOLUTIONS* CLIVE LLRW DISPOSAL FACILITY
LICENSE NO: UT2300249; RML #UT 2300249

CONDITION 35 COMPLIANCE REPORT; APPENDIX A: FINAL REPORT FOR THE CLIVE DU PA MODEL

SAFETY EVALUATION REPORT
VOLUME 2

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for Utah Department of Environmental Quality

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Appendix A – REGULATORY BASIS FOR THE REVIEW OF THE DEPLETED URANIUM PERFORMANCE ASSESSMENT

As noted in Section 1 of the main report, Utah Administrative Code (UAC) Rule R313-25-9,[1] "Technical Analyses," requires that any facility that proposes to dispose of significant quantities of depleted uranium (DU) must submit a performance assessment demonstrating that the performance standards specified by the U.S. Nuclear Regulatory Commission (NRC) in Title 10 of the Code of Federal Regulations (10 CFR) Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," and corresponding State of Utah rules will be met for a minimum of 10,000 years and that additional simulations be performed for the period when the peak dose occurs (which will be well beyond 10,000 years) and the results of the simulations be analyzed qualitatively. Listed below are the performance standards (objectives) from 10 CFR Part 61, with the corresponding State of Utah rules noted.

10 CFR 60, Subpart C—Performance Objectives

§ 61.40 General requirement.

Land disposal facilities must be sited, designed, operated, closed, and controlled after closure so that reasonable assurance exists that exposures to humans are within the limits established in the performance objectives in §§ 61.41 through 61.44.

§ 61.41 Protection of the general population from releases of radioactivity [UAC R313-25-20].

Concentrations of radioactive material which may be released to the general environment in ground water, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable.

§ 61.42 Protection of individuals from inadvertent intrusion [UAC-R313-25-21].

Design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site and occupying the site or contacting the waste at any time after active institutional controls over the disposal site are removed.

§ 61.43 Protection of individuals during operations [UAC-R313-25-22].

Operations at the land disposal facility must be conducted in compliance with the standards for radiation protection set out in part 20 of this chapter, except for releases of radioactivity in effluents from the land disposal facility, which shall be governed by § 61.41 of this part. Every reasonable effort shall be made to maintain radiation exposures as low as is reasonably achievable.

§ 61.44 Stability of the disposal site after closure [UAC-R313-25-23].

[1] A new Section 6, "Director Review of Application," was added to R313-25 in April 2014. Thus, all references to R313-25 Sections 6 to 28 in prior documents are now to Sections 7 to 29.

The disposal facility must be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required.

§ 61.12 Specific technical information [UAC-R313-25-8].

The specific technical information must include the following information needed for demonstration that the performance objectives of subpart C of this part and the applicable technical requirements of subpart D of this part will be met:

(a) A description of the natural and demographic disposal site characteristics as determined by disposal site selection and characterization activities. The description must include geologic, geotechnical, hydrologic, meteorologic, climatologic, and biotic features of the disposal site and vicinity.

(b) A description of the design features of the land disposal facility and the disposal units. For near-surface disposal, the description must include those design features related to infiltration of water; integrity of covers for disposal units; structural stability of backfill, wastes, and covers; contact of wastes with standing water; disposal site drainage; disposal site closure and stabilization; elimination to the extent practicable of long-term disposal site maintenance; inadvertent intrusion; occupational exposures; disposal site monitoring; and adequacy of the size of the buffer zone for monitoring and potential mitigative measures.

(c) A description of the principal design criteria and their relationship to the performance objectives.

(d) A description of the design basis natural events or phenomena and their relationship to the principal design criteria.

(e) A description of codes and standards which the applicant has applied to the design and which will apply to construction of the land disposal facilities.

(f) A description of the construction and operation of the land disposal facility. The description must include as a minimum the methods of construction of disposal units; waste emplacement; the procedures for and areas of waste segregation; types of intruder barriers; onsite traffic and drainage systems; survey control program; methods and areas of waste storage; and methods to control surface water and groundwater access to the wastes. The description must also include a description of the methods to be employed in the handling and disposal of wastes containing chelating agents or other non-radiological substances that might affect meeting the performance objectives in subpart C of this part.

(g) A description of the disposal site closure plan, including those design features which are intended to facilitate disposal site closure and to eliminate the need for ongoing active maintenance.

(h) An identification of the known natural resources at the disposal site, the exploitation of which could result in inadvertent intrusion into the low-level wastes after removal of active institutional control.

(i) A description of the kind, amount, classification and specifications of the radioactive material proposed to be received, possessed, and disposed of at the land disposal facility.

(j) A description of the quality assurance program, tailored to LLW disposal, developed and applied by the applicant for the determination of natural disposal site characteristics and for quality assurance during the design, construction, operation, and closure of the land disposal facility and the receipt, handling, and emplacement of waste.

(k) A description of the radiation safety program for control and monitoring of radioactive effluents to ensure compliance with the performance objective in § 61.41 of this part and occupational radiation exposure to ensure compliance with the requirements of part 20 of this chapter and to control contamination of personnel, vehicles, equipment, buildings, and the disposal site. Both routine operations and accidents must be addressed. The program description must include procedures, instrumentation, facilities, and equipment.

(l) A description of the environmental monitoring program to provide data to evaluate potential health and environmental impacts and the plan for taking corrective measures if migration of radionuclides is indicated.

(m) A description of the administrative procedures that the applicant will apply to control activities at the land disposal facility.

(n) A description of the facility electronic recordkeeping system as required in § 61.80.

§ 61.13 Technical analyses [UAC-R313-25-9].

The specific technical information must also include the following analyses needed to demonstrate that the performance objectives of subpart C of this part will be met:

(a) Pathways analyzed in demonstrating protection of the general population from releases of radioactivity must include air, soil, groundwater, surface water, plant uptake, and exhumation by burrowing animals. The analyses must clearly identify and differentiate between the roles performed by the natural disposal site characteristics and design features in isolating and segregating the wastes. The analyses must clearly demonstrate that there is reasonable assurance that the exposure to humans from the release of radioactivity will not exceed the limits set forth in § 61.41.

(b) Analyses of the protection of individuals from inadvertent intrusion must include demonstration that there is reasonable assurance the waste classification and segregation requirements will be met and that adequate barriers to inadvertent intrusion will be provided.

(c) Analyses of the protection of individuals during operations must include assessments of expected exposures due to routine operations and likely accidents during handling, storage, and disposal of waste. The analyses must provide reasonable assurance that exposures will be controlled to meet the requirements of part 20 of this chapter.

(d) Analyses of the long-term stability of the disposal site and the need for ongoing active maintenance after closure must be based upon analyses of active natural processes such as erosion, mass wasting, slope failure, settlement of wastes and backfill, infiltration through covers over disposal areas and adjacent soils, and surface drainage of the disposal site. The analyses must provide reasonable assurance that there will not be a need for ongoing active maintenance of the disposal site following closure.

Appendix B – SUPPLEMENTAL INTERROGATORIES PERTAINING TO THE EVAPOTRANSPIRATION COVER

Based on its review of Round 3 Interrogatories, the Utah Department of Environmental Quality (DEQ) had additional questions regarding the performance of the evapotranspiration (ET) cover. These concerns were discussed with Energy*Solutions* and, on August 11, 2014, DEQ submitted additional interrogatories for Energy*Solutions* to address (DEQ 2014). DEQ also requested that Energy*Solutions* conduct some additional bounding calculations with HYDRUS to provide greater transparency as to how the percolation model performed. Energy*Solutions*' replies are documented in its August 18, 2014, "Responses to August 11, 2014 – Supplemental Interrogatories Utah LLRW Disposal License RML UT 2300249 Condition 35 Compliance Report" (ES 2014).

DEQ has reviewed the August 18, 2014, responses and has determined that the information provided is not sufficient to resolve the supplemental interrogatories. DEQ's discussion of these deficiencies is provided in this appendix. In general, there needs to be much more description of how the analysis proceeded from the input data to the results. The following are some specific examples from the Energy*Solutions* response where DEQ believes that additional information and explanations are necessary.

B.1 Supplemental Interrogatory Comment 1

1) Demonstrate why 20 HYDRUS runs are sufficient to capture the parameter uncertainty.

Summary of Energy*Solutions*' Response:

Energy*Solutions* discusses how the van Genuchten's alpha (or "α") and *n* in the Surface Layer and Evaporative Zone Layer soils, and the saturated hydraulic conductivity (K_{sat}) in the radon barriers were varied at random in the HYDRUS runs from distributions implied by the summary statistics for the Rosetta data (Schaap 2002) for van Genuchten's α and *n*, and from values published in Benson et al. (2011) and the Energy*Solutions* design specification for K_{sat}. The K_{sat} values for the radon barriers were sampled from developed distributions derived from data provided in Whetstone (2011) and Benson et al. (2011). Energy*Solutions* scaled the distributions for van Genuchten's α and *n* in GoldSim to reflect the more coarse nature of the cell structure. The following statement is the most direct response from Energy*Solutions* with respect to whether 20 HYDRUS runs are adequate to capture the parameter uncertainty:

> *Given the scaling that is appropriate for the Clive DU PA model, in effect the range of the inputs to HYDRUS are much greater than the range used in the Clive DU PA model for the Genuchten's* alpha a*nd n parameters (by a factor of the square root of 28). This has the effect of smoothing across the range of the parameters of interest in the Clive DU PA model, but was considered a reasonable approach assuming that the regression implied by the HYDRUS runs could be used directly across a smaller range of values in the Clive DU PA*

model. Because of this difference in scaling, 20 HYDRUS runs are considered sufficient to support the Clive DU PA v1.2 model.

In addition, the resulting water contents and infiltration rates in the Clive DU PA model seem reasonable given the conceptual model for the ET cap (see responses to Comments #7 through #9).

DEQ Critique

The response provided to this comment did not address the comment satisfactorily.

DEQ understands that the regressions [Equations 39 and 40 of Appendix 5 to the depleted uranium performance assessment (DU PA) (Neptune 2014b)] were created as simplified surrogate models that relate percolation from the base of the cover and water content in each layer of the cover profile to hydraulic properties of the cover soils. This regression model was developed based on output from HYDRUS from 20 sets of input parameters.

Because only 20 cases were used for the simulations, the tails of the distributions describing the hydraulic properties are poorly sampled, and more extreme cases may be inadequately represented. Consequently, the regressions may represent average or mean conditions sufficiently but may not adequately represent the more extreme cases. No information has been provided to demonstrate that the extreme cases in the tails of the distributions are adequately represented by the regression, or that 20 cases are sufficient to capture the effects of the tails of the distributions. For heavy-tailed distributions such as those used for hydraulic properties, many more simulations would be needed to adequately represent events driven by properties associated with the tails of the distributions.

The predictions in Energy*Solutions* (2014) Figure 5 (see the discussion on Comment 7 below) suggest that the process of developing the regression model has resulted in predictions that are centered more around the mean behavior and that are insensitive to the tails. The percolation predicted from the regression varies within a narrow range of around 0.3 millimeters per year (mm/yr), whereas percolation predicted by HYDRUS predictions for all realizations ranges from approximately 0.01 mm/yr to 10 mm/yr. The response suggests that this insensitive behavior is due to the variance reduction in the hydraulic properties to account for spatial averaging, but another plausible reason is that the regression is based on mostly mean behavior and is relatively insensitive to extremes represented by the hydraulic properties in the tails of the distributions.

A well-documented justification is needed that demonstrates that Equations 39 and 40, based on predictions from 20 simulations using 20 sets of randomly sampled properties, adequately predict the percolation rate and the water contents for cases near the mean and more extreme cases in the tails of the distributions.

In addition, the analysis fails to adequately account for (1) correlations between parameters α and K_{sat} in the same soil layer, and (2) correlations between the values of each parameter within different soil layers. These deficiencies need to be resolved. DEQ also notes that the Energy*Solutions* response contains no substantive discussion of how and why scaling was conducted and how it impacts the results. This discussion must be provided.

B. 2 Supplemental Interrogatory Comment 2

2) The Table 9 HYDRUS parameters do not appear to "bound" the α, *n*, and K_{sat} distributions. For example, in the distribution, K_{sat} ranges from 0.0043 to 52 cm/day, but in the 20 HYDRUS runs K_{sat} only ranged from 0.16 to 10.2 cm/day.

Summary of Energy*Solutions*' Response:

As described in the response to Comment 1, the three input parameters (variables) were randomly drawn from input distributions for the 20 HYDRUS runs. Twenty observations are drawn at random from the distribution for K_{sat}. These randomly drawn values range from 0.16 to 10.2 centimeters per day (cm/day), with a mean of 2.28 cm/day. Energy*Solutions* considers these values sufficiently extreme to evaluate the influence of K_{sat} on the HYDRUS model outputs, and, therefore, to determine the influence of K_{sat} on the water content and infiltration model outputs.

Energy*Solutions* also notes that K_{sat} is not a predictor of the HYDRUS infiltration endpoint in either the linear or quadratic regressions (that is, it is not close to statistical significance and has a correlation of negative 0.10 with infiltration). However, Energy*Solutions* did include K_{sat} in the regression models for water content in the upper layers, and these regression models were used in the Clive DU PA version 1.2 GoldSim model (Neptune 2014a; hereafter referred to as "DU PA v1.2"). Energy*Solutions* further states that "*It was shown very clearly in the sensitivity analysis for the Clive DU PA v1.2 GoldSim model that K_s* [K_{sat}] *is not a sensitive parameter for any of the PA* [performance assessment] *model endpoints*."

DEQ Critique:

The response indicates that the input "*values are considered sufficiently extreme to evaluate the influence of K_s on the HYDRUS model outputs, and hence to determine the influence of K_s on the water content and infiltration model outputs*." The basis for the conclusion "considered sufficiently extreme" needs to be demonstrated rather than stipulated.

As cited in the response to Comment 1 (above), a well-documented justification is needed that demonstrates that Equations 39 and 40, based on predictions from 20 simulations using 20 sets of randomly sampled properties, adequately predict the percolation rate and the water contents for cases near the mean and more extreme cases in the tails of the distributions. This demonstration should also provide a physical basis for excluding some of the variability in key hydraulic properties normally considered to affect percolation strongly, such as K_{sat} in the shallow cover-system layers (i.e., the Surface Layer and the Evaporative Zone Layer). Any exclusion of this parameter or its full range of variability from other aspects of modeling, correlation, or sensitivity analysis should also be justified. Although the Clive DU PA v1.2 appears superficially to have illustrated that the output was not sensitive to K_{sat}, this conclusion may be the result of predictions from a cover hydrology model for which unrealistic parameters were used as input (e.g., changing some parameter values but not others for a given soil layer). A separate quantitative demonstration is needed showing that Equations 39 and 40, based on the 20 sets of hydraulic properties used as input, are representative.

B.3 Supplemental Interrogatory Comment 3

3) NUREG/CR-7028 (Benson et al. 2011) gives the "in-service hydraulic conductivity" as ranging from $7.5{\times}10^{-8}$ to $6.0{\times}10^{-6}$ m/s [0.7 to 52 cm/day], with a mean of $4.4{\times}10^{-7}$ m/s [3.8 cm/day]. Instead of using the provided distribution (i.e., log-triangular with a minimum, maximum, and most likely), ES/Neptune constructed a lognormal distribution with a mean and standard deviation of 0.691 and 6.396 cm/day, respectively. Provide the justification for this approach. For example, the selection of 0.0043 cm/day as the lower end of the K_{sat} distribution requires justification (Appendix 5, p.41). It is not clear why a design parameter value should be used when adequate field data are available. The number chosen by the Licensee for the lower end of the distribution range in the GoldSim implementation is 163 times lower than the lowest value in the range specified within the NUREG guidance (see Section 13.0 of Appendix 5, Unsaturated Zone Modeling to the Clive DU PA). We believe that use of the design parameter biases the K_{sat} distribution in a non-conservative manner.

Summary of Energy*Solutions*' Response:

Energy*Solutions* indicates that the lognormal distribution was not fit with the value of 0.0043 but that this value was used to truncate the distribution after fitting so that lower values could not be drawn at random. Energy*Solutions* notes that the Division of Radiation Control (DRC) has not provided a reference to the cited log-triangular distribution, and that a log-triangular distribution with a minimum of 0.7 cm/day, a maximum of 52 cm/day, and a mean of 3.8 cm/day is not possible to formulate. Energy*Solutions* also expressed concerns about using artificially truncated distributions and distributions with noncontinuous modes.

Energy*Solutions* observed that the mean of the lognormal distribution is about 3.9 cm/day, which is very close to the value suggested in Comment 3 (3.8 cm/day). Also, the range of the lognormal distribution exceeds the range of values suggested in Comment 3. Energy*Solutions* further indicates that K_{sat} is not used in the regression equations for infiltration rate because this variable is not statistically significant and K_{sat} is not a sensitive parameter (variable) for any of the end points in the GoldSim model.

DEQ Critique:

The Energy*Solutions* response to Comment 3 has not demonstrated that the distribution of K_{sat} used for the HYDRUS modeling adequately represents the range of conditions that might be realized for a "naturalized" cover, i.e., one that has undergone pedogenesis as described in NUREG/CR-7028 (Benson et al. 2011). To account for the higher K_{sat} in NUREG/CR-7028 (Benson et al. 2011), the lognormal distribution for K_{sat} was re-fit by the Licensee using an abnormally large $\log(\sigma)$ of 6.396. This provides an unrealistic distribution of K_{sat} that substantially overweights K_{sat} in the lower range.

This, in turn, has the general effect of artificially increasing apparent capillary barrier effects in the DU PA Model v1.2, i.e., at the interface between a relatively lower-permeability zone (the combined Surface Layer and the Evaporative Zone Layer, having a mean K_{sat} value in the DU PA Model v1.2 of 4.46 cm/day) and a relatively higher-permeability zone (the Frost Protection Layer, having a mean K_{sat} value in the DU PA Model v1.2 of 106.1 cm/day). When the Licensee assumes in HYDRUS that the K_{sat} value for the lower-permeability zone can be as small as 0.0042 cm/day, the ratio in hydraulic conductivity between the higher-permeability zone and the lower-permeability zone can thus be as large as 25,000. This creates in the model an extremely potent artificial, non-realistic capillary barrier at the Evaporative Zone Layer/Frost Protection Layer interface that, in an unrealistic way, reduces infiltration below that interface to extremely small or even negligible values.

The primary model hydraulic conductivity value for the higher-permeability zone in the DU PA Model v1.2, 106.1 cm/day, may already be unrealistic, since the assemblage of soil particles in the Frost Protection Layer is proposed to be a random, poorly-sorted mixture of grain sizes, with smaller grains being as small as clay. The Frost Protection Layer is not characterized in terms of actual grain size distribution in the DU PA Model v1.2, other than to say that particle sizes can range from 16-inch diameter to clay size. The hydraulic conductivity assigned to it is arbitrary. The assigned value is representative of a sandy loam, which is a very poor representation of the proposed Frost Protection Layer. A mixture of poorly-sorted grain sizes, as found in the Frost Protection Layer, tends to greatly diminish the hydraulic conductivity of a soil compared to a relatively well-sorted mixture. Further exacerbating the problem in the DU PA Model v1.2 is that the hydraulic conductivity values assumed in HYDRUS for the lower-permeability zone are additionally allowed to be 163 times lower than the lowest specified value in the NUREG range for in-service hydraulic conductivity (Benson et al. 2011).

The rationale for dramatically increasing $\log(\sigma)$ to account for the higher K_{sat} associated with pedogenesis or "naturalization" has not been provided and is counterintuitive. The $\log(\sigma)$ should at least be similar for as-built and naturalized covers and may, in fact, be lower for naturalized covers because pedogenic processes ameliorate hydraulic anomalies inherent in the cover from construction. NUREG/CR-7028 (Benson et al. 2011) indicates that pedogenesis tends to transform in-service hydraulic conductivity values to as-built values found in a much higher, but a more restricted, range. The mean should shift upward during naturalization as structure develops, reflecting overall increase in K_{sat} and α rather than a broader range.

As noted previously, while the Clive DU PA Model v1.2 may have illustrated that the output was not sensitive to K_{sat}, this conclusion may be the result of predictions from a cover hydrology model for which unrealistic parameters were used as input. Insensitivity of infiltration to hydraulic conductivity would be expected if inappropriate input parameter values are used so as to create in the model an unjustified, artificial capillary barrier effect. Normally, in the absence of a capillary barrier, infiltration is very sensitive to hydraulic conductivity. As stated by Alvarez-Acosta et al. (2012):

> *A soil hydraulic property that is often a required input to simulation models is the saturated hydraulic conductivity, K_s. It is one of the most important soil physical properties for determining infiltration rate and other hydrological processes…. In hydrologic models, this is a sensitive input parameter and is one of the most problematic measurements at field-scale in regard to variability and uncertainty.*

Thus, the insensitivity of deep infiltration to K_{sat} reported in the Clive DU PA is not sufficient to dismiss the need for demonstrating the efficacy of the parameters used for the HYDRUS input in Appendix 5 to the DU PA Model v1.2.

B.4 Supplemental Interrogatory Comment 4

4) Provide justification for using the Rosetta database, as appropriate for an engineering earthen cover.

Summary of Energy*Solutions*' Response:

Energy*Solutions* indicates that the class average values of soil hydraulic function parameters for the 12 soil textural classifications in Rosetta were developed from 2,134 soil samples for water retention and 1,306 soil samples for saturated hydraulic conductivity that were based primarily on agricultural land.

Energy*Solutions* notes that the Rosetta database is widely used and has been successful in many applications, in some cases performing better than the Carsel and Parrish (1988) database. Energy*Solutions* further indicates that the soil hydraulic properties from both databases are provided in the HYDRUS software platforms and the choice of one over the other by the modeler is considered a matter of preference. Energy*Solutions* provides additional justification by citing the origin of the data, results of infiltration studies, and extensive use of the database by other researchers.

Energy*Solutions* also provides additional discussion and explanation of the origin of the hydraulic parameters and distributions used for the ET cover system

DEQ Critique:

This interrogatory asked for justification for using the Rosetta database for an *engineered earthen cover*. The response goes to great length comparing the attributes of the Rosetta database to other databases, none of which are populated with data for engineered earthen covers. Most of the databases are for agricultural soils, many of which have been tilled. Their relevance to an engineered earthen cover has not been demonstrated. The response has shown, however, that many of the mean values of hydraulic properties used as input are, to some extent, in reasonable agreement with those associated with engineered earthen covers, as described in NUREG/CR-7028 (Benson et al. 2011). On the other hand, as discussed in the Supplemental Interrogatory Comment 3 (see Section B.3), the low-end value in the range of hydraulic conductivity used in the GoldSim model is 163 times lower than the lowest specified value in NUREG/CR-7028 for in-service hydraulic conductivity. The low-permeability tail of the distribution is overweighted, and variability is not properly accounted for.

One response to the interrogatory, if it could be substantiated using data, would be that the Rosetta database is not based on engineered earthen cover soils and should not be assumed to be representative, but point-wise comparisons between hydraulic recommended properties in Rosetta and those in NUREG/CR-7028 demonstrate that the mean hydraulic properties are similar in both cases. However, as pointed out above, the variability assumed in the hydraulic properties chosen to represent the soils in the DU PA Model v1.2 is not appropriately characterized, and this limitation in the model biases the modeling results greatly.

While it is true that engineered soils undergo pedogenesis and become more like natural soils over time, it is important to follow NUREG/CR-7028 guidelines. The fact that the GoldSim model uses values for its K_{sat} distribution that, at the low end, are two orders of magnitude lower than specified in NUREG/CR-7028 , and that the low-permeability range of values is overweighted, does not lead to confidence that the GoldSim model is set up appropriately.

Furthermore, in the GoldSim model as implemented, it is assumed for the input parameter values that there is no correlation between log(α) and log(K_{sat}). When databases based on natural soils are used, it is important to account for correlation between these two parameters. Strong correlation between log(α) and log(K_{sat}) (with $R^2 = 0.9$) has been established for the largest database in North America, as well as for the largest database in Europe [see Sections 4.1.1.1 and 4.4.1 of the safety evaluation report (SER)]. The two correlation equations are quite similar. Furthermore, a mathematical relationship similar to the correlation equations has been developed from fundamental soil physics theory by Guarracino (2007).

Failure to account for this correlation, or other, significant correlations (e.g., correlation in individual parameter values between different cover-system soil layers), leads to unrealistic modeling. As stated in GoldSim's User Manual, Appendix A: Introduction to Probabilistic Simulation (GTG 2013):

> *Ignoring correlations, particularly if they are very strong (i.e., the absolute value of the correlation coefficient is close to 1) can lead to physically unrealistic simulations. In the above example, if the solubilities of the two contaminants were positively correlated (e.g., due to a pH dependence), it would be physically inconsistent for one contaminant's solubility to be selected from the high end of its possible range while the other's was selected from the low end of its possible range. Hence, when defining probability distributions, it is critical that the analyst determine whether correlations need to be represented.*

The response has also clarified that the Surface Layer and Evaporative Zone Layer were each assigned a geometric mean hydraulic conductivity of 5×10^{-7} meters per second (m/s). This hydraulic conductivity is considered unrealistically low for in-service near-surface layers (e.g., <10 feet deep) that will be densely structured due to wet-dry cycling, freeze-thaw cycling, and biota intrusion by roots, insects, etc. This unrealistically low K_{sat} at or near the surface may have choked off infiltration in the HYDRUS model and exacerbated runoff, thereby limiting deeper ingress of meteoric water in the profile and under-predicting percolation. As discussed in Section 4.1.1.1 of the SER, the unrealistically low near-surface K_{sat} value, combined with the unrealistically high Frost Protection Layer K_{sat} value, which is inputted into the model, would tend to create in the model an unrealistic, artificial capillary barrier at the top of the higher permeability layer that would inappropriately render modeled values of infiltration extremely low. Soils at the surface develop significant structure and generally are much more permeable than those much deeper in the profile. Energy*Solutions* will need to provide additional evidence that this assumed hydraulic conductivity did not artificially bias the HYDRUS modeling.

The response to Comment 4 also indicates that NUREG/CR-7028 recommends using a single measurement from a single site to define α. This is an incorrect interpretation of the design recommendations in NUREG/CR-7028. The recommendation in NUREG/CR-7028 to use $\alpha = 0.2$ 1/kilopascal (kPa) applies when reliable site-specific information is not available and when a single typical value (not a range of values) is desired. It is based on an interpretation of the dataset presented in NUREG/CR-7028 as accounting for scale-dependent hydraulic properties. The HYDRUS modeling in Appendix 5 used an α that is approximately one order of magnitude lower than the recommendation in NUREG/CR-7028. This α is based in part on historic measurements made at Colorado State University on core samples obtained at the Clive site by Bingham Environmental (1991), which are known to be too small and too disturbed to adequately represent in-service conditions. The relevancy of this historic data from Bingham Environmental is dubious, at best.

B.5 Supplemental Interrogatory Comment 5

5) a) Provide additional explanation/justification for the assumed surface boundary condition and the sensitivity of the HYDRUS results to the boundary conditions.

   b) Also, why is a linear regression the optimal surface response for the design?

Summary of Energy*Solutions*' Response:

a) Energy*Solutions* indicates that the surface boundary conditions for the HYDRUS cover model consisted of 100 years of daily values of precipitation, potential evaporation, and potential transpiration, and that these boundary conditions were repeated 10 times for a 1,000-year (ky) simulation. Energy*Solutions* notes that sensitivity under different climate scenarios was not evaluated because there is no scientific evidence suggesting climate change in the next 10 ky and that current science suggests that the future climate is likely to be drier in the next 10k y. Furthermore, Energy*Solutions* contends that the probabilistic bounds are reflected within the variability contained in the historical data record and the small probability of significant changes in future climate over the next 10 ky.

b) Extensive statistical analysis has been conducted to evaluate possible model abstraction from HYDRUS to GoldSim for water content in each of the five upper layers of the ET cover, and for infiltration into the waste. Energy*Solutions* described how van Genuchten's α and n in the surface and evaporative zone soil layers and saturated hydraulic conductivity (K_{sat}) in the two lower radon barriers were varied in HYDRUS, to form the basis for the regression modeling (i.e., model abstraction). After creating a set of 20 observations that contained both inputs (i.e., explanatory or independent variables in a regression) and outputs (i.e., outputs of interest from the HYDRUS runs, which included water content in the upper five layers and infiltration into the waste layer), Energy*Solutions* ran linear and quadratic regression models and found that the results were not very sensitive to K_{sat}. Energy*Solutions* concluded that, "*Despite the r-squared values, which are decent for at least the top two layers, the models are very weak. The dominant factors are the intercept term for all water content endpoints, a negative value of* n *for water content in the top two layers, and positive values of alpha for the other layers and the infiltration rate*." Energy*Solutions* also concluded that "*Overall, the regression models are not very good. Although the r-squared values look reasonable for some of these regression models, explanations of the regression models are difficult to* *provide. That is, statistical fits are reasonable, but practical explanation is difficult. Consequently, the linear regressions were used for simplicity*."

The linear regressions for all water content endpoints show the same effect that the predicted values are greater than for the quadratic regressions. For infiltration, the linear regression indicated considerably greater values of infiltration flux than the quadratic regression, and the quadratic regression implied a large proportion of negative values. For these reasons, Energy*Solutions* used the linear regression models over the quadratic regression models.

DEQ Critique:

The interrogatory asked for additional justification for the assumed surface boundary condition. The response explains how the boundary condition was created but does not provide justification for the boundary condition. Two shortcomings need to be addressed explicitly.

First, the repetition of the same 100-year periods 10 times to represent the climatic conditions over a 1000-year period of climatic input must be justified quantitatively. For all practical purposes, this simulation strategy will provide essentially the same output for each 100-year period in the record. This demonstration should show that the meteorological conditions over a 1000-year period, including extreme events expected over a 1000-year period, can be represented adequately using a sequence of repeated 100-year records. Normally, longer periods of time involve greater variability in the data. This requested demonstration should also show that the impacts of these extremes on the hydrological response of the cover are adequately represented.

Second, the justification should show that the hydrological behavior at the upper boundary (i.e., surface of the cover) is reasonable and within expected norms. This has not been demonstrated in Appendix 5 (Neptune 2014b), and the unrealistically low K_{sat} assigned to the Surface Layer (see Comment 4) in combination with likely capillary-barrier effect artifacts in the model may have choked off infiltration into the cover profile. At a minimum, water-balance graphs should be presented for typical and wet years showing the temporal behavior of each of the primary cumulative water-balance variables for the cover (e.g., precipitation, runoff, soil water storage, evapotranspiration, percolation). These graphs, and their associated discussion, should demonstrate that the surface boundary is represented adequately and that predictions are within expected norms.

The absence of climate change considerations should also be presented in the context of the most recent climate science, which does show systematic shifts in climate throughout North America within the next 10,000 years, if not sooner. An explanation should also be provided as to why climate change is not relevant at the Clive site when it has been considered in performance assessments for other disposal facilities in the region (e.g., the Monticello U mill tailings disposal facility).

The Energy*Solutions* response also provides an extensive discussion to justify the efficacy of Equations 39 and 40 in Appendix 5. However, these outcomes may have been biased by the unrealistically low K_{sat} assigned to the Surface Layer and Evaporative Zone Layer (see Comment 4), which, in combination with likely capillary-barrier effect artifacts in the model, may have choked off infiltration into the cover profile. The efficacy of Equations 39 and 40 should be revisited once the impacts of the unrealistically low K_{sat} assigned to the Surface Layer and Evaporative Zone Layer (see Comment 4) have been investigated.

As an alternative to the linear regression, DEQ/SC&A fit an exponential equation to the van Genuchten α, *n*, and K_{sat} input data and the HYDRUS-calculated fluxes (Figure B-1). The triangles shown in Figure B-1 are the fluxes calculated using the following exponential fit: Flux = $45.465 \times \alpha^{1.4408} \times n^{-1.332} \times K_{sat}^{-0.445}$. For large fluxes, the exponential fit does not appear to be much better than the linear fit, but for small fluxes (which tend to result when the van Genuchten α is small), the exponential fit is much better than the linear fit.

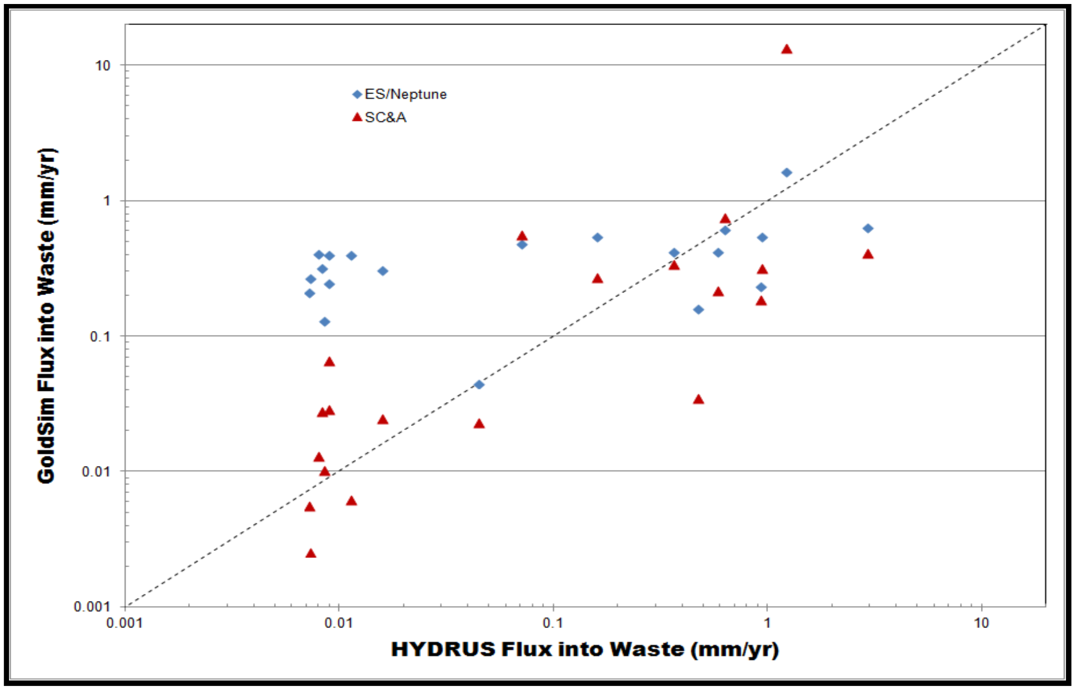

Figure B-1 – GoldSim versus HYDRUS infiltration flux

B.6 Supplemental Interrogatory Comment 6

6) To summarize the 20 HYDRUS results, Appendix 5, Section 12.9 states: "*Infiltration flux into the waste zone ranged from 0.007 to 2.9 mm/yr, with an average of 0.42 mm/yr, and a log mean of 0.076 mm/yr for the 20 replicates*." In addition to this statement, provide the results for each HYDRUS run so that the results can be matched to the input data.

Summary of Energy*Solutions*' Response:

Energy*Solutions* refers to an Excel file provided to DRC (i.e., "CHB#6, Hydrus params and results.xlsx") for infiltration and water content results matched with input data for the 20 replicates. This file includes the 20 replicate values of van Genuchten α and *n* for the surface and evaporative zone layers, and K_{sat} for the radon barriers. Infiltration and water content data are calculated as averages over the last 100 years of a 1,000-year simulation (i.e., from 900 to 1,000 years). Energy*Solutions* also presents several figures plotting volumetric water content and infiltration versus log(α), and versus log(K_{sat}). Based upon these figures, Energy*Solutions* concludes that there is no correlation between infiltration and the K_{sat} of the radon barriers for the 20 HYDRUS-1D replicates, but there is a correlation between infiltration and α of the two uppermost surface layers. Energy*Solutions* also indicates that there is no apparent correlation between infiltration and *n* of the two uppermost surface layers but that there is a correlation between infiltration and α as well as a correlation between volumetric water content in the lower layers (frost protection and radon barriers) and α of the two uppermost surface layers.

The Excel file also includes calculations of mean, log mean, min, and max of the 20 replicate input and output values.

DEQ Critique:

This interrogatory requested that the results be provided for each HYDRUS run so that the results can be matched to the input data. The response included a spreadsheet summarizing percolation from the base of the cover and water contents from the HYDRUS analysis. However, the output from HYDRUS was not provided.

The output from HYDRUS should be included in the report and presented in a manner consistent with the practice associated with design and evaluation of water-balance covers (i.e., ET covers). Water-balance graphs should be reported showing the key water-balance quantities, and discussion should be provided that demonstrates that the predictions are within expected norms for water-balance covers. This type of presentation and discussion has not been provided in Appendix 5 or in subsequent responses to interrogatories.

The Energy*Solutions* response also discusses graphs in an attached spreadsheet and indicates that these graphs demonstrate that there is no relationship between percolation from the base of the cover and K_{sat} of the radon barrier. This finding may have been biased by the unrealistically low K_{sat} assigned to the Surface Layer and Evaporative Zone Layer (see Comment 4), which, in combination with likely capillary-barrier effect artifacts in the model, may have choked off infiltration into the cover profile. This issue needs to be reevaluated once the impact of the K_{sat} assigned to the near-surface layers has been addressed.

B.7 Supplemental Interrogatory Comment 7

7) The HYDRUS and GoldSim calculated infiltration rates (and perhaps other intermediary results) need to be provided in the report, so that the reviewers do not have to delve into the code's output files. For example, provide dot plots of the infiltration rates through the surface layer and/or provide a statistical summary of the infiltration rates that were sampled in GoldSim.

Summary of Energy*Solutions*' Response:

Energy*Solutions* provided Figure 4, which shows the sorted infiltration through each layer of the ET cover and into the waste zone for the 20 Hydrus-1D replicates where infiltration is the average infiltration over the last 100 years of a 1,000-year simulation. A second figure presented by Energy*Solutions* (Figure 5) shows the same result for HYDRUS-1D flux into waste presented in the first figure, along with the infiltration into waste calculated by the GoldSim DU PA Model v1.2 for 1,000 replicates using the linear regression equation where infiltration is based on van

Genuchten α and *n*. Energy*Solutions* concludes that GoldSim infiltration has a smaller range than the HYDRUS-1D results.

Energy*Solutions* provides additional discussion pertaining to the inputs and distributions in HYDRUS and GoldSim as well as the scaling assumptions assumed in GoldSim. Energy*Solutions* also presents infiltration statistics for the HYDRUS-1D and GoldSim model results and concludes that the mean infiltration values are similar (0.422 mm/yr for HYDRUS and 0.344 mm/yr for GoldSim).

DEQ Critique:

This interrogatory requested that the percolation rates reported by HYDRUS be presented directly in the report. The response includes Figure 4, which shows "infiltration" in mm/yr for various layers in the cover and Figure 5, which shows "infiltration" (interpreted as percolation from the base of the cover) from HYDRUS and predicted with the regression equation, i.e., Equation 39 in Appendix 5.

The quantities shown in Figure 4 need more explanation. Infiltration is defined as the flux of water across the atmosphere-soil interface in response to precipitation. Water movement below the surface is a volumetric flux, and the flux from the base of the cover and into the waste is the percolation rate for the cover. Do these quantities represent the net flux from the base of each layer in the cover? The "infiltration" for the surface layer report in Figure 4 also raises concern, as the results indicate that the unrealistically low K_{sat} assigned to the Surface Layer and Evaporative Zone Layer (see Comment 4), in combination with likely capillary-barrier effect artifacts in the model, may have choked off infiltration into the cover profile and unrealistically limited downward movement of water. A discussion of the HYDRUS predictions in the context of cumulative water-balance quantities and expected norms for water-balance covers could address this issue.

As indicated in the discussion associated with Comment 1, the predictions shown in Figure 5 illustrate that the percolation rate from the regression used in GoldSim is considerably different from the predictions made with HYDRUS and is essentially insensitive to the hydraulic properties used as input. The lack of sensitivity is attributed to the reduction in log-variance to address spatial averaging, but another plausible explanation is that Equation 39 reflects central conditions adequately but extreme conditions in the tailings inadequately. Yet another plausible explanation is the likely capillary-barrier effect artifacts in the model, which would minimize or possibly even exclude infiltration of water to greater depths, so long as evaporation could remove it from the upper two soil layers. Furthermore, evapotranspiration rates in the model are likely too high, since they do not account for accumulation of gravel at the surface over time, which would tend to greatly diminish evaporation. A quantitative demonstration and explanation is needed to address this issue.

The response should also indicate how and why temporal scaling was incorporated into the hydraulic properties, as indicated by the term "spatio-temporal" used in the response to the interrogatory. Temporal scaling should account explicitly for the temporal evolution of the distribution of hydraulic properties due to pedogenic effects. No discussion has been provided regarding a temporal evolution of hydraulic properties. If temporal scaling has not been incorporated, then scale matching should be described as spatial rather than spatio-temporal.

The Energy*Solutions* response should also indicate why conventional spatial averaging procedures for correlated hydraulic properties were not used in the spatial scaling process from point scale measurements in the Rosetta database to grid scale in the model. Spatial scaling from a point measurement to model grid scale must account for upscaling of the mean to address measurement bias as well as downscaling of the log-variance in a manner consistent with the spatial correlation structure of engineered but degraded-over-time in-service earthen cover soils. The response should indicate how these factors are addressed by reducing the log-variance by the square root of the sample size in the Rosetta database.

The discussion below illustrates DEQ's mathematical (as opposed to hydrogeologic) concerns with the way infiltration is being abstracted into GoldSim from the HYDRUS results.

1) The linear regression equation that has been programmed into GoldSim does not give results that are consistent with what is calculated by HYDRUS (i.e., for a given pair of α and *n*, the regression equation result in GoldSim does not approximate the HYDRUS result). This is demonstrated by Figure B-1 (See DEQ Critique to Supplemental Interrogatory Comment 5).

2) As acknowledged by Energy*Solutions* in its responses to Supplemental Interrogatories 1 and 2, due to scaling effects the ranges for α and *n* that have been programmed into GoldSim are more narrow than those in HYDRUS (i.e., in HYDRUS, α ranges from 0.001883 to 0.3021, but in GoldSim, α only ranges from 0.005 to 0.0493; likewise, in HYDRUS, *n* ranges from 1.029 to 1.883, but in GoldSim *n* only ranges from 1.060 to 1.540). See Figure B-2 and Figure B-3 for complementary cumulative distribution (CCD) comparisons that were prepared by SC&A utilizing Energy*Solutions* HYDRUS results and the Neptune (2014b), Table 1 GoldSim α and *n* distributions.

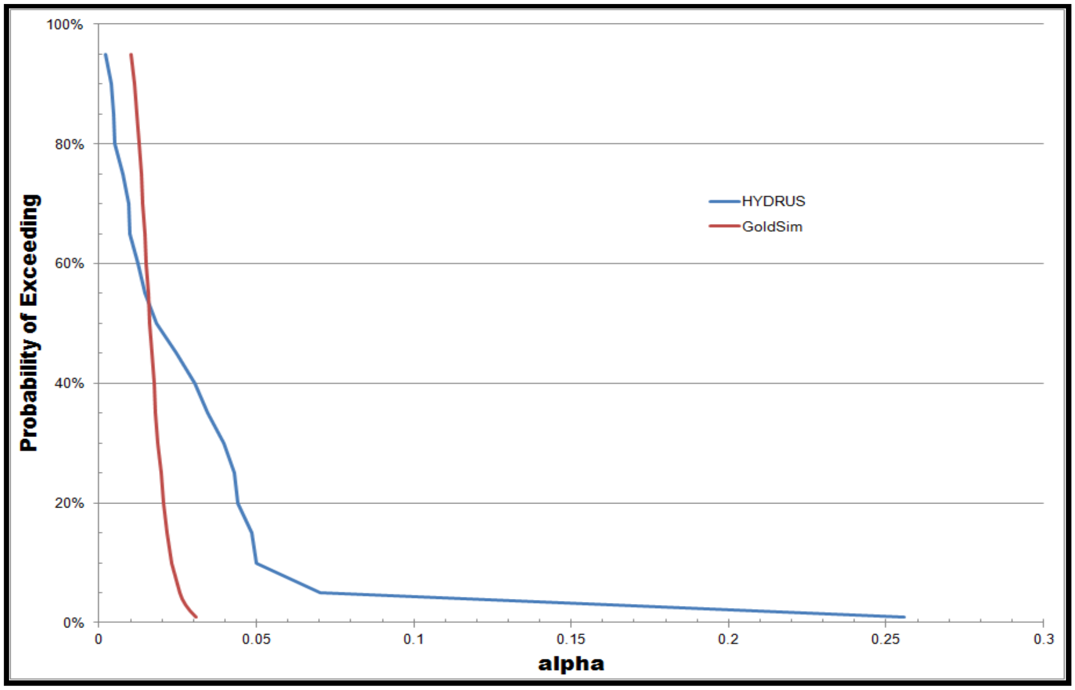

Figure B-2 – Complementary cumulative distribution of HYDRUS and GoldSim α parameters

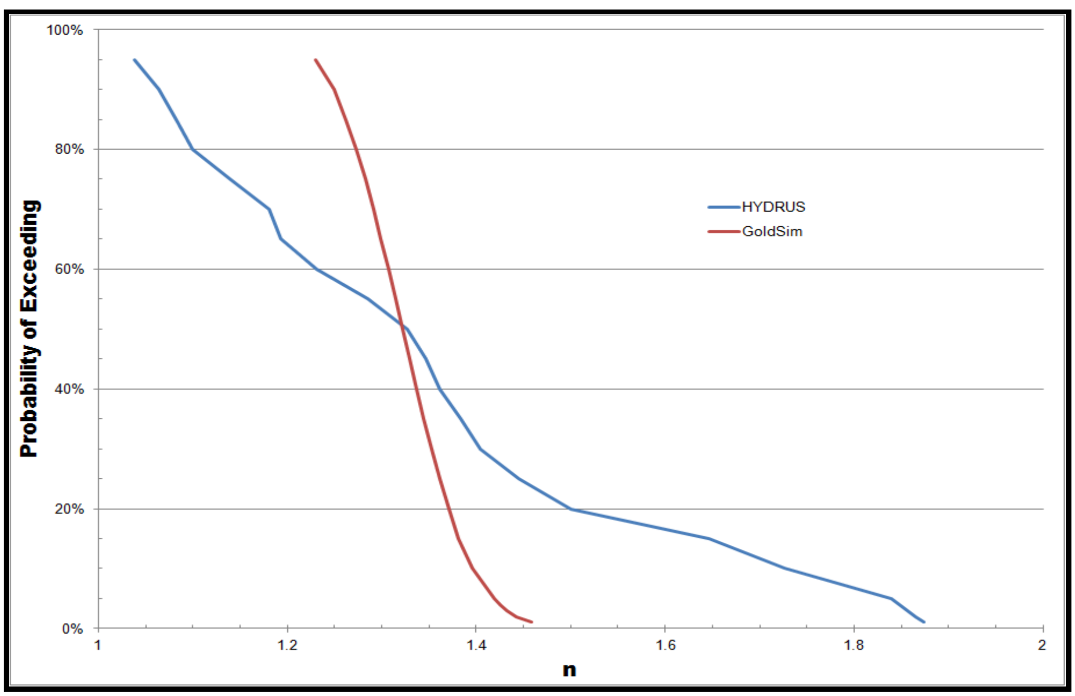

Figure B-3 – Complementary cumulative distribution of HYDRUS and GoldSim *n* parameters

The CCD comparison in Figure B-4 shows the effect of these two mathematical considerations on the resulting GoldSim infiltration rate. This infiltration CCD is very similar to Figure 5 of the Energy*Solutions* Response to Supplemental Interrogatories, except that it is rotated 90 degrees.

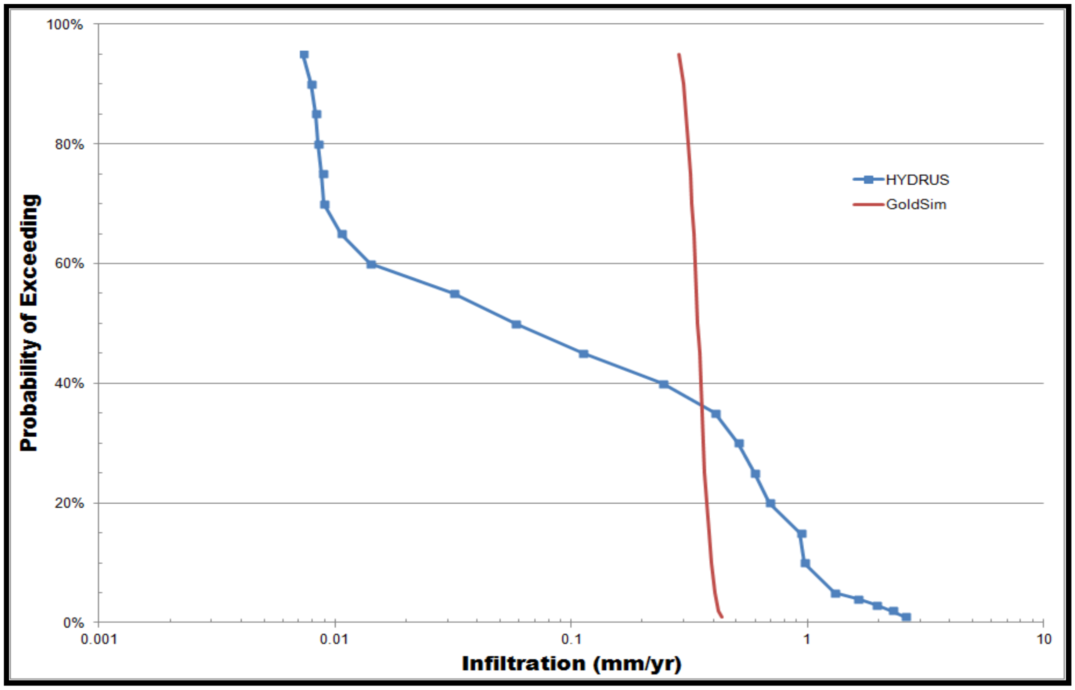

Figure B-4 – Complementary cumulative distribution of HYDRUS and GoldSim infiltration fluxes

Note that GoldSim was not re-run for these analyses. Instead, the GoldSim equations were programmed into an Excel Crystal Ball file, and 10,000 realizations were run. Also, the reason the GoldSim CCDs are smoother than the HYDRUS CCDs is that the GoldSim CCDs have 10,000 points, whereas the HYDRUS CCDs have only 20.

B.8 Supplemental Interrogatory Comment 8

8) a) Demonstrate that the fitted equations for water content and infiltration (Appendix 5, Equations 39 and 40, and Table 10) give "reasonable" results when compared to HYDRUS.

   b) For example, provide an explanation for why K_{sat} is insensitive to the infiltration rates.

Summary of Energy*Solutions*' Response:

a) Energy*Solutions* notes that the DU PA Model v1.2 was used to generate 1,000 realizations of the net infiltration rate and the cover layer volumetric water contents. Energy*Solutions* provides a table that compares the maximum, minimum, means, and standard deviations with the 20 HYDRUS simulation results. Energy*Solutions* also presents a number of histogram plots that compare results between the Clive DU PA Model v1.2 and the 20 HYDRUS simulations (H1D). Energy*Solutions* concludes that, for all parameters, the means are comparable and the standard deviations are larger for the HYDRUS results.

b) Energy*Solutions* provides two flux-versus-time plots. Energy*Solutions* hypothesizes that the reason that the net infiltration rates simulated by HYDRUS are likely not sensitive to the saturated hydraulic conductivity is because of the high evaporation rates from the surface layer and because the radon barriers do not have a large influence on the water balance of the cover system.

DEQ Critique:

This interrogatory asked for demonstration that Equations 39 and 40 provide realistic predictions relative to the predictions from HYDRUS. The response provides a number of graphs showing that the predictions in the Clive DU PA Model v1.2 using Equations 39 and 40 are similar to those from HYDRUS in the sense of the mean but exhibit less variability than the predictions in HYDRUS. The reduced variability in the percolation predicted by Equation 39 is attributed to the reduction in log-variance to address spatial averaging, but another plausible explanation is that Equation 39 reflects central conditions adequately, but extreme conditions in the tailings inadequately. A quantitative demonstration and explanation is needed to resolve this issue.

This interrogatory also asked for an explanation of the lack of sensitivity of percolation rate to K_{sat}. The response on pages 25 and 26 (un-numbered figures) shows that water is isolated in the surface layer. However, using an unrealistically low K_{sat} for the Surface Layer and Evaporative Zone Layer, in combination with likely capillary-barrier effect artifacts in the model (see Comment 4), may have choked off infiltration into the cover profile and trapped water at the surface, thereby limiting downward movement of water unrealistically and artificially impacting the significance of K_{sat} of the radon barrier. A discussion of the HYDRUS predictions in the context of cumulative water-balance quantities and expected norms for water-balance covers could address this issue.

B.9 Supplemental Interrogatory Comment 9

9) Compare the moisture contents calculated using the fitted equations to the Bingham (1991, Table 6 and/or Appendix B) Clive site measured Unit 4 moisture contents, and rationalize any differences.

Summary of Energy*Solutions*' Response:

Energy*Solutions* calculated volumetric water contents using the fitted equations extracted from the GoldSim DU PA Model v1.2. Energy*Solutions* then ran the model for 1,000 simulations to generate 1,000 values of water content for the Evaporative Zone Layer (Unit 4 soil).

Gravimetric water contents for Unit 4 soils, at depths less than or equal to 2 feet [near the depth of the Evaporative Zone Layer (0.5 to 1.5 feet)], were obtained from Bingham Environmental (1991, Table 6) and converted to volumetric values.

Volumetric water contents from GoldSim (1,000 replicates), from HYDRUS-1D (20 replicates), and the six measured values from Table 6 are plotted in a figure, and Energy*Solutions* concludes that the volumetric water contents calculated with the fitted equation in GoldSim are well bounded by the Bingham Environmental (1991) data from Table 6. Energy*Solutions* indicates further agreement is that the mean volumetric water content value in Table 6 is 0.285, while the mean from the 1,000 GoldSim model replicates is slightly higher at 0.294, and the mean value of the 20 HYDRUS-1D replicates is 0.286, nearly identical to the Bingham Environmental (1991) samples.

DEQ Critique:

The comparison with HYDRUS is remarkably good. However, the comparison with Equation 39 is not so good. Equation 39 seems to predict θ between 0.27 and 0.31 for nearly all cases, whereas the data are over a much broader range.

B.10 Supplemental Interrogatory Comment 10

10) Finally, we believe that there is a typo on p. 42 of Appendix 5; in the statement: "A ***normal*** distribution was fit to the 50th and 99th percentiles ….", we believe it should be a ***lognormal*** distribution.

Summary of Energy*Solutions*' Response:

Energy*Solutions* notes that the 50th and 99th percentiles were used to fit a lognormal distribution, and the value of 0.00432 was then used to truncate the distribution.

DEQ Critique:

The interrogatory is answered satisfactorily.

B.11 Supplemental Interrogatory Comment 11

DRC provided Energy*Solutions* with an Excel file, "Clive Hydrus Sensitivity Recommend REV2.xlsx," which contains suggested or proposed combinations of input values for the HYDRUS runs used to support the Clive DU PA.

Summary of Energy*Solutions*' Response:

Energy*Solutions* provides a lengthy discussion of the fallacy of conducting and drawing conclusions from this type of deterministic analysis. Energy*Solutions* expresses further concerns related to the parameter input values as well as the "warm up" simulations.

Energy*Solutions* ran the nine HYDRUS-1D simulations requested by DRC, and results showing the range from minimum to maximum infiltration (into waste zone), along with the results from the original 20 HYDRUS-1D simulations, were shown in a figure. Energy*Solutions* concludes that, "*Despite the implementation of the high Ks values requested by the Division, infiltration in the new 9 simulations is generally lower than for the original 20 HYDRUS-1D simulations. This is largely due to setting residual water content to zero, which effectively increases the water holding capacity of each soil layer. Overall, the Clive DU PA model provides a reasonable range for the input parameters for the hydraulic properties given the currently available data and information, and the HYDRUS runs for the nine additional combinations of single values for inputs adds no further insight*."

DEQ Critique:

DEQ requested a sensitivity analysis for a reasonable range of parameters to evaluate whether the model responds within expected norms for a water-balance cover. This request has been made in part because Appendix 5 provides inadequate documentation to demonstrate the efficacy of the HYDRUS model and its realism relative to expected norms for a water-balance cover. Moreover, Appendix 5 indicates that predictions made by the model are insensitive to hydraulic parameters (notably K_{sat}) generally known to have a strong influence on predictions made by HYDRUS and similar models. For example, the unrealistically low K_{sat} for the Surface Layer and Evaporative Zone Layer (see Comment 4) may have choked off infiltration into the cover profile and trapped water at the surface, thereby limiting downward movement of water unrealistically and artificially impacting the significance of K_{sat} of the radon barrier. As explained throughout this document, there are significant concerns that the HYDRUS model may not be realistic and may be biasing the analyses in the performance assessment. An assessment of the efficacy of the HYDRUS model in the context of expected norms is essential to resolve this issue.

The response goes to great length to dismiss the requested sensitivity analysis as not based on reasonable soil properties and as being inconsistent with a performance assessment approach. The response justifies the criticism of the soil properties by citing databases for soil properties unrelated to engineered earthen covers (e.g., the National Resource Conservation Service database) or data reports known to contain measurements on samples that are too small to represent in-service conditions and collected with antiquated techniques that are known to cause disturbance of soil structure (e.g., the 1991 Bingham Environmental report).

Despite these criticisms, the requested analyses apparently were conducted, but the output was not included or presented comprehensively in the responses. The findings from these simulations should be tabulated and reported, and water-balance graphs should be prepared and discussed in the context of the mechanisms known to influence the hydrology of water-balance covers. A thoughtful discussion would help justify the use of the HYDRUS model and build confidence in the output.

B.12 Supplemental Interrogatory Comment 12

This comment dealt with available disposable volumes under the "Huntsman Agreement." The discussion is not relevant to the ET cover. The DEQ position regarding the Huntsman Agreement is described in Section 3.4.1 of the main report.

B.13 References

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Appendix C – STATUS OF INTERROGATORIES

C.1 Introduction

This report provides a synopsis of the status of all interrogatories as of April 2015, when the Safety Evaluation Report (SER) on the Energy*Solutions* Clive depleted uranium performance assessment (DU PA) Model (Neptune 2011, 2014a) was delivered to State of Utah Division of Environmental Quality (DEQ).[1] Most of the interrogatories have been closed based on responses provided by Energy*Solutions* to Rounds 1, 2, and 3 interrogatories. Some interrogatories have been closed based on DEQ analyses included in the DU PA SER. Some remain open as summarized in this appendix. Some will be resolved by imposing license conditions on any license amendment addressing disposal of depleted uranium (DU) waste at the Energy*Solutions* Clive, Utah, facility.

Relevant documents, in addition to the DU PA SER, include the following:

DEQ Interrogatories	Energy*Solutions* Responses
Round 1 – February 28, 2014: Division of Radiation Control (DRC), Utah Department of Environmental Quality, "Energy*Solutions* Clive LLRW Disposal Facility: Utah LLRW Disposal License Renewal Application (Condition 35 (RML UT 2300478), Section 2300249); Compliance Report (June 1, 2011) Including Final Report, Version 1.0 (Appendix A) and Appendices to Appendix A and Compliance Report, Revision 1 (November 8, 2013): Round 1 Interrogatories," February 2014.	License No: UT2300249; RML #UT 2300249 – Condition 35 Compliance Report, Revision 1; Responses to February 2014 Round 1 Interrogatories. March 31, 2014
Round 2 – March 27, 2014: Division of Radiation Control (DRC), Utah Department of Environmental Quality, "Energy*Solutions* Clive LLRW Disposal Facility: Utah LLRW Disposal License – Condition 35 (RML UT 2300249) Compliance Report (June 1, 2011) Including Final Report, Version 1.0 (Appendix A) and Appendices 1–17 to Appendix A and Compliance Report, Revision 1 (November 8, 2013): Round 2 Interrogatories," May 2014.	RML UT2300249 – Condition 35 Compliance Report Responses to Round 2 Interrogatories. June 17, 2014

[1] All references to "the DU PA SER" in this appendix are to this April 13, 2015, final version. Previously, an initial Draft SER was issued on July17, 2014, Revision 1 to the Draft on September 16, 2014, and Revision 2 to the Draft on March 31, 2015.

Round 3 – July 1, 2014: Division of Radiation Control (DRC), Utah Department of Environmental Quality, Division of Radiation Control, Utah Department of Environmental Quality, 2014c. "Energy*Solutions* Clive LLRW Disposal Facility: Utah LLRW Disposal License – Condition 35 (RML UT 2300249); Compliance Report (June 1, 2011) Including Final Report, Version 1.0 (Appendix A) and Compliance Report, Revision 1 (November 8, 2013) and Revised DU PA (June 5, 2014) Including Final Report Version 1.2. and Appendices 1–18: Round 3 Interrogatories," July 2014.	Appendix E, Responses to July 1, 2014 Round 3 Interrogatories, to Utah Radioactive Material License Condition 35 (RML UT2300249) Compliance Report, Revision 2. July 8, 2014

C.2 List of Interrogatories and DEQ Conclusions

1) Interrogatory CR R313-25-19-01/3: Intergenerational Consequences

DEQ Conclusion:

No changes were made to Sections 4.1.2.11 and 6.4 of the Clive DU PA Model, version 1.2 (Neptune 2014a; hereafter "the DU PA Model v1.2") with regard to the implication that either an undiscounted value of $1,000 per person-rem or a discounted value of $2,000 per person-rem may be used, and the text continues to include discount factors of 3 percent and 7 percent. No discussion on the U.S. Nuclear Regulatory Commission's (NRC's) position on intergenerational impacts, as defined in NUREG/BR-0058 (NRC 2004), has been added to Sections 4.1.2.11 and 6.4.

Although Energy*Solutions* has added text describing intergenerational consequences, it continues to use the out-of-date $1,000 per person-rem value. Contrary to Energy*Solutions*' interpretation, the NRC has not supplemented the $1,000 per person-rem non-discounted value with a $2,000 per person-rem discounted value. Rather, as indicated in NUREG/BR-0058, Revision 4, the NRC has *superseded* the $1,000 per person-rem with the value of $2,000 per person-rem for all benefit/cost analyses, including intergenerational non-discounted analyses. Thus, DEQ continues to take issue with the cost values presented in Du PA Model v1.2, Section 6.4. That said, doubling the costs in the DU PA Model v1.2, Table 10, would not change any of the conclusions of the as low as reasonably achievable (ALARA) analysis (i.e., "the ALARA costs involved are very small"). Therefore, DEQ considers that this interrogatory is closed.

2) Interrogatory CR R313-25-8(5)(a)-02/1: Deep Time

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

3) Interrogatory CR R313-25-8(5)(a)-03/3: Deep Time – Sediment and Lake Concentrations

DEQ Conclusion:

Energy*Solutions* provided a deep time supplemental analysis (DTSA) (Neptune 2014b, 2015a), which effectively made moot the DU PA Model v1.2 deep time analysis, as well as much of Interrogatory 03. The DU PA SER, Section 5.1.1 presents DEQ's evaluation of the DTSA. In this section, DEQ continues to disagree with Energy*Solutions* on the need to present the results of the qualitative analysis in the form of doses rather than concentrations, and on the usefulness of similar, but non-low-level waste/DU-specific, regulatory criteria (e.g., 40 CFR 61.252(a) permissible radon flux) as a comparison metric. For example, in the DU PA SER, Section 5.1.1, DEQ calculated the deep time radon flux, converted that flux into an annual dose, and compared that dose to a dose criterion currently in the process of being proposed by the NRC as being applicable to the 10 CFR Part 61 protective assurance period (NRC 2014a, 2014b, 2014c).

Since it was based on the original DU PA v1.0 and v1.2 deep time model and because the Energy*Solutions* DTSA (Neptune 2014b, 2015a) makes moot the original deep time analyses, Interrogatory 03 is considered closed, with the understanding that DEQ and Energy*Solutions* continue to disagree on portions of the interrogatory as described above.

4) Interrogatory CR R313-25-8(4)-04/1: References

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories.

5) Interrogatory CR R313-25-7(2)-05/2: Radon Barrier

DEQ Conclusion:

Based on several unresolved issues related to the evapotranspiration (ET) cover, DEQ indicated in the DU PA SER that the cover design was deficient. Therefore, this interrogatory remains open. The unresolved issues are as follows:

Evapotranspiration Cover – There are still a number of unresolved issues with respect to the selection of parameter ranges, distributions, and correlations, as well as the modeling approach and predicted sensitivities. These concerns are detailed in Appendix B. Further, because the model-predicted infiltration rates will be sensitive to the hydraulic properties assigned to each ET layer, DEQ recommends that Energy*Solutions* develop hydraulic properties for the cover system based on the approach outlined by Dr. Craig H. Benson in Appendix F to this SER. Issues related to this portion of the performance assessment cannot be closed until these concerns have been resolved.

Clay Liner – As with the ET cover, there is still an unresolved concern that K_{sat} values will increase greatly over time, and that the α and K_{sat} values assumed for modeling flow through the liner must either be correlated or a sensitivity analysis be conducted to demonstrate that the lack of correlation assumed does not adversely affect the modeling results. In addition, there are problems with assumed liner hydraulic conductivity values. Furthermore, the DU PA Model v1.2 does not account for liner degradation over time. These issues must be resolved before DEQ can determine the adequacy of this portion of the DU PA.

Infiltration – Before the adequacy of the DU PA can be determined, additional modeling of the ET cover infiltration rates must be conducted based on in-service hydraulic properties and correlated log(α) and log(K_{sat}) values as described in Appendix E. Without this information, DEQ is unable to conclude if the infiltration rates predicted by the DU GoldSim model are reliable or representative of future conditions (i.e., ≥ 10,000 years).

Erosion of Cover – Before the adequacy of the DU PA can be determined, Energy*Solutions* needs to clarify certain issues relating to Appendix 10 to the DU PA Model v1.2 (June 5, 2014; Neptune 2014g) as described in Section 4.4.2 of the SER. DRC is currently reviewing a license amendment request to use an ET cover of similar design to that proposed for the Federal Cell in the DU PA. Any recommendations and conclusions from that review must be applied to the proposed Federal Cell as well.

Effect of Biologicals on Radionuclide Transport – Energy*Solutions* has not shown that the cover system is sufficiently thick or designed with adequate materials to protect the cover system or the underlying bulk waste in the embankments against deep rooting by indigenous greasewood (a species known to penetrate soils at other sites down to 60 feet) or other plants, or against biointrusion by indigenous ants or mammals (e.g., with maximum documented burrowing depths greater than the proposed cover thickness). Higher rates of infiltration are typically associated with higher contaminant transport rates. Under Utah rules, infiltration should be minimized [see UAC Rule R313-25-25(3) and (4)]. DEQ cannot determine the adequacy of the DU PA until Energy*Solutions* accounts for greater infiltration through the cover system at the proposed Federal Cell embankment due to biointrusion by plant roots and by animals.

Frost Damage – With the current proposed Federal Cell design, Energy*Solutions* should account in modeling for substantial disruption of near-surface layers above and within the radon barriers by frost, with accompanying decreases in ET and increases for initially low-permeability soil in both hydraulic conductivity and correlated α values, which could affect modeled infiltration rates and radon release rates. UAC R313-25-25(3) and (4) require a licensee to minimize infiltration; therefore, Energy*Solutions* must model infiltration under realistic long-term assumed site conditions before DEQ can determine that this requirement has been met.

6) Interrogatory CR R313-25-7(2)-06/1: Gully Model Assumptions

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

7) Interrogatory CR R313-25-8(4)(b)-07/2: Applicability of NRC Human Intrusion Scenarios

DEQ Conclusion:

Closed, based on the analyses and discussion in Section 4.3 of the DU PA SER. For example, an inadvertent intruder searching for sand and clay would soon recognize that he was drilling into other waste overlying the DU waste and cease operations. Other proposed scenarios have lower consequences than those evaluated by Energy*Solutions* and DEQ.

8) Interrogatory CR R313-25-8(4)(a)-08/1: Groundwater Concentration Endpoints

DEQ Conclusion:

DEQ has stated that no DU waste containing recycled uranium will be allowed to be disposed at Clive, so this interrogatory is closed.

9) Interrogatory CR R313-25-19-09/1: Definition of ALARA

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories.

10) Interrogatory CR R313-22-32(2)-10/3: Effect of Biologicals on Radionuclide Transport

DEQ Conclusion:

As discussed in the DU PA SER (Section 4.4.3), Energy*Solutions* has not shown that the cover system is sufficiently thick or designed with adequate materials to protect the cover system or the underlying bulk waste in the embankments against deep rooting by indigenous greasewood (a species known to penetrate soils at other sites down to 60 feet) or other plants, or against biointrusion by indigenous ants or mammals (e.g., with maximum documented burrowing depths greater than the proposed cover thickness). Higher rates of infiltration are typically associated with higher contaminant transport rates. Under Utah rules, infiltration should be minimized [see UAC Rule R313-25-25(3) and (4)]. DEQ cannot determine the adequacy of the DU PA until Energy*Solutions* accounts for greater infiltration through the cover system at the Federal Cell embankment due to biointrusion by plant roots and by animals. Therefore, this interrogatory remains open.

11) Interrogatory CR R313-25-20-11/1: Inadvertent Human Intruder

DEQ Conclusion:

Closed. See Interrogatory CR R313-25-8(4)(b)-07/2: Applicability of NRC Human Intrusion Scenarios.

12) Interrogatory CR R313-25-20-12/2: Selection of Intrusion Scenarios

DEQ Conclusion:

Closed. See Interrogatory CR R313-25-8(4)(b)-07/2: Applicability of NRC Human Intrusion Scenarios.

13) Interrogatory CR R313-25-7-13/1: Reference for Long-Term Climatic Cycles

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

14) Interrogatory CR R313-25-8(4)(d)-14/2: Sediment Mixing

DEQ Conclusion:

Energy*Solutions* provided a DTSA (Neptune 2014b, 2015a), which effectively made moot the DU PA Model v1.2 deep time analysis, as well as Interrogatory 14. Provided that all DU is disposed of below the current ground surface level, and the deep time analysis is as described in the DTSA (rather than as in the DU PA Model v1.2, Sections 5.1.8, 5.4.7, and 6.5, and Appendix 13), Interrogatory 14 is closed.

15) Interrogatory CR R317-6-6.3(Q)-15/2: Uranium Chemical Toxicity

DEQ Conclusion:

As stated in Section 5.2 of the DU PA SER:

> *Since both the calculated uranium hazard indices and the implied hazard indices for the acute or chronic driller intrusion scenarios are very small, DEQ considers this portion of the DU PA to be adequate with all issues resolved.*

Because the uranium indices are very small, this interrogatory is closed.

16) Interrogatory CR R313-25-8(4)(a)-16/2: Radon Production and Burrowing Animals

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories.

17) Interrogatory CR R317-6-6.3(Q)-17/1: Uranium Parents

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

18) Interrogatory CR R313-25-8(5)(a)-18/3: Sediment Accumulation

DEQ Conclusion:

In its Round 3 response, Energy*Solutions* stated that "*discussions of aeolian sedimentation rates have been revised. For example, reference to a rate of 0.1 to 3 mm/year has been removed. Note that sedimentation rates for aeolian deposition were not used in the model.*" However, the Energy*Solutions* Round 3 response to Interrogatory 05 states:

> *Aeolian deposition will probably cover the existing sediments (rather than mixing with them completely as is currently modeled). This will result in considerably smaller concentrations in deep time than currently presented in the PA model, with the potential to be as low as, or even lower than, background concentrations. Note the in recent correspondence with Dr. Charles (Jack) Oviatt, the pit wall has been re-interpreted. Originally Dr. Oviatt interpreted the top 70 cm as reworked Gilbert Lake materials but now does not believe that the Gilbert Lake reached Clive, and, consequently, that the top 70 cm are probably aeolian deposits (…). If this is the case, then aeolian deposition can play a more important role in site stability and site protection, including providing a layer of protection against radon transport.*

Energy*Solutions* provided a DTSA (Neptune 2014b, 2015a), which effectively made moot the DU PA Model v1.2 deep time analysis. The DU PA SER, Section 5.1.1 presents DEQ's evaluation of the DTSA. As stated in the DU PA SER, Section 5.1.1, Neptune (2014b and 2015a) used a mean intermediate lake sedimentation amount of 2.82 meters, which, when coupled with the mean intermediate lake duration of 500 years, gives a sedimentation rate of 5.64 millimeters per year (mm/yr). DEQ's consultant, Dr. Paul Jewell, provided information indicating that Great Basin Lake sedimentation rates ranged from 0.12 to 0.83 mm/yr. The DEQ analysis provided in the DU PA SER, Section 5.1.1 utilized a range of intermediate lake sedimentation rates, based on data provided by Neptune (2014b, 2015a) and Dr. Jewell.

For aeolian deposition, Neptune (2015b) based its radon flux calculation on the information obtained during a December 2014 field investigation (Neptune 2015b). DEQ (and its consultant, Dr. Jewell) have reviewed the results of the field investigation, and agree with its results regarding the depth of aeolian deposition in the Clive area and the length of time over which that deposition accumulated.

DEQ continues to disagree with Energy*Solutions* on the intermediate lake sedimentation rate, and concludes that additional study of this issue is necessary. Thus, this interrogatory remains open.

19) Interrogatory CR R313-25-8(5)(a)-19/1: Reference for Sediment Core Records

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories.

20) Interrogatory CR R317-6-2.1-20/2: Groundwater Concentrations

DEQ Conclusion:

Gullies that form on the embankment have the potential to increase the infiltration rate on the embankment, and an increased infiltration rate has the potential to increase the groundwater concentration of radionuclides leached from the DU. The Clive DU PA Model includes a gully formation model, however, the DU PA Model v1.2 (p. 3) states that "*No associated effects, such as…local changes in infiltration are considered within the gullies*." As indicated in the DU PA SER, Section 4.4.2, "Erosion of the Cover," Energy*Solutions* explained these omissions as follows in its Interrogatory 20 Round 2 response:

> *While the formation of some of the gullies may actually erode through significant depths of the evapotranspirative cover, the ratio of gully footprint to total evapotranspirative cover surface area remains minimal.*

In its Round 3 response to Interrogatory 70, Energy*Solutions* further stated that "*The influence of gully formation on infiltration and radon transport is negligible given the current below grade disposal design*." The reason given is "*that only a small fraction of the cover would have gullies extending through the surface and evaporative zone layers to the top of the frost protection layer*."

Nonetheless, DU PA SER Section 4.4.2 concluded the following:

> *Before the DU PA can be determined to be adequate, Energy*Solutions *needs to clarify certain issues relating to Appendix 10 to the DU PA Model v1.2 (…) as described in* [SER] *Section 4.4.2. DRC is currently reviewing a license amendment request to use an ET cover of similar design to that proposed for the Federal Cell in the DU PA. Any recommendations and conclusions from that review must be applied to the proposed Federal Cell as well.*

Therefore, this interrogatory remains open.

21) Interrogatory CR R313-25-8(4)(d)-21/2: Infiltration Rates

DEQ Conclusion:

As discussed in the DU PA SER (Section 4.1.1.1), there are still a number of unresolved issues with respect to the selection of parameter ranges, distributions, and correlations, as well as the modeling approach and predicted sensitivities. These concerns are detailed in Appendix B to the DU PA SER. Before the DU PA can be determined to be adequate, additional modeling of the ET cover infiltration rates must be conducted based on in-service hydraulic properties and correlated log(α) and log(K_{sat}) values as described in Appendix E. Without this information, DEQ is unable to conclude if the infiltration rates predicted by the DU GoldSim model are reliable or representative of future conditions (i.e., ≥ 10,000 years). Therefore, this interrogatory remains open.

22) Interrogatory CR R313-25-7-22/1: Definition of FEPs

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

23) Interrogatory CR R313-25-7(2)-23/1: Canister Degradation and Corrosion

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

24) Interrogatory CR R313-15-101(1)-24/3: Utah Regulations

DEQ Conclusion:

Section 1.3 of the DU PA Model v1.2 should have been revised to cite UAC R313-25-9(5)(a) as the source for the quotation on page 18. However, this revision was not made. Revisions were also not made to Section 4.2.1, page 22, of the Conceptual Site Model report (Neptune 2014c).

Energy*Solutions* had also stated that governing Utah rules would be cited in Sections 1 and 1.3 of the Conceptual Site Model report. No such changes have been made to Section 1, and there is no Section 1.3 in either v1.0 or v1.2 of the DU PA Model (Neptune 2011, 2014a).

DEQ requests that the requested changes be made in the further revisions to the performance assessment. However, because this interrogatory deals with editorial rather than substantive technical issues, Energy*Solutions*' failure to make the requested changes does not impact on DEQ's review of the DU PA. Therefore, this interrogatory is closed.

25) Interrogatory CR R313-25-7(9)-25/1: Disposition of Contaminants in UF_6

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

26) Interrogatory CR R313-25-8(4)(a)-26/2: Radon Diffusion in the Unsaturated Zone

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

27) Interrogatory CR R313-25-8(4)(a)-27/3: Diffusion Pathway Modeling

DEQ Conclusion:

As indicated in the DU PA SER, Section 4.2, DEQ showed that the Clive DU PA Model v1.2 takes little credit for radon attenuation by the ET cover. Rather, most of the radon attenuation is provided by the material (e.g., non-DU material) lying between the DU and the ET cover. Because the ET cover is not being credited with attenuating the radon, the cracks, fissures, animal burrows, and plant roots that form over time and may provide preferential diffusion pathways would not greatly affect the resulting ground surface radon flux calculated by the Clive DU PA Model v1.2. Therefore, the DU PA SER determined that the Clive DU PA Model v1.2 radon flux calculation is conservative, and thus acceptable. Therefore, Interrogatory 27 is closed.

28) Interrogatory CR R313-25-8(4)(a)-28/3: Bioturbation Effects and Consequences

DEQ Conclusion:

As stated in the DU PA SER, Section 4.4.3, "Effect of Biologicals on Radionuclide Transport":

> *Energy*Solutions *has not shown that the cover system is sufficiently thick or designed with adequate materials to protect the cover system or the underlying bulk waste in the embankments against deep rooting by indigenous greasewood (a species known to penetrate soils at other sites down to 60 feet) or other plants, or against biointrusion by indigenous ants or mammals (e.g., with maximum documented burrowing depths greater than the proposed cover thickness). Higher rates of infiltration are typically associated with higher contaminant transport rates. Under Utah rules, infiltration should be minimized [see UAC Rule R313-25-25(3) and (4)]. DEQ cannot determine the adequacy of the DU PA until* *Energy*Solutions *accounts for greater infiltration through the cover system at the proposed Federal Cell embankment due to biointrusion by plant roots and by animals.*

Therefore, this interrogatory remains open.

29) Interrogatory CR R313-25-8(5)(a)-29/2: Limitation to Current Conditions of Society and the Environment

DEQ Conclusion:

Closed. See Interrogatory CR R313-25-8(4)(b)-07/2: Applicability of NRC Human Intrusion Scenarios.

30) Interrogatory CR R313-25-8(5)(a)-30/1: Inclusion of SRS-2002 Data in the Sensitivity Analysis

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

31) Interrogatory CR R313-25-8(5)(a)-31/3: Tc-99 Content in the Waste and Inclusion in the Sensitivity Analysis

DEQ Conclusion:

Closed, based on recommendation not to include recycled uranium in DU waste. See Section 5.3 of the DU PA SER.

32) Interrogatory CR R313-25-8(4)(a)-32/3: Effect of Other Potential Contaminants on PA

DEQ Conclusion:

Energy*Solutions*' Round 1 interrogatory response is satisfactory. The revised sensitivity analysis results report (Neptune 2014d) shows that the effect of other potential contaminants on the intruder doses is trivial. See also the discussion in Section 4.3 of the DU PA SER. Therefore, this interrogatory is closed.

33) Interrogatory CR R315-101-5.3(6)-33/1: Clarification of the Phrase "Proof-of-Principle Exercise" and Sensitivity to Uranium Oral Reference Dose Factors

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

34) Interrogatory CR R313-25-8(5)(a)-34/3: Intent of the PA

DEQ Conclusion:

Closed, based on responses to Round 3 interrogatories (July 8, 2014).

35) Interrogatory CR R313-25-19-35/1: Reference for Cost per Person-Rem

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

36) Interrogatory CR R313-25-8(4)(a)-36/1: Ant Nest Extrapolations

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

37) Interrogatory CR R313-25-8(5)(a)-37/2: Distribution Averaging

DEQ Conclusion:

The interrogatory is directed toward a general statement made in Section 5.2, "Distribution Averaging," of the DU PA Model v1.0 (Neptune 2011), rather than toward a specific parameter. In its Round 2 response, Energy*Solutions* provided a general description of how distribution averaging was performed and included several examples (e.g., Unit 4 porosity, annual rainfall). Energy*Solutions* also provided a general description of how linear and non-linear relationships are modeled and again provided examples (e.g., dose conversion factors, uranium concentration). As a general description of how distribution averaging has been performed in the Clive DU PA Model, the Energy*Solutions* response is satisfactory, and Interrogatory 37 is considered closed.

38) Interrogatory CR R313-25-8(5)(a)-38/3: Figures 5 and 11 in FRV1

DEQ Conclusion:

Section 4.2 of the DU PA SER discusses exposure scenarios involving the deeper aquifer and demonstrates that doses will be small (e.g., see Table 4-5). In addition, Section 6.1.2 of the DU PA SER stated that "*a characterization program needs to be established to gain a better understanding of the spatial and temporal characteristics of the hydrogeologic system, particularly as related to the lower aquifer*." This characterization program needs to focus on the lower, confined aquifer and the extent to which it is connected to the upper aquifer. Additional characterization of the hydrogeologic system will be a condition for any license amendment. Therefore, this interrogatory is closed.

39) Interrogatory CR R313-25-8(5)(a)-39/1: Figure 6 Caption

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

40) Interrogatory CR R313-25-8(5)(a)-40/3: Figures 7, 8, 9, 10, and 11

DEQ Conclusion:

Closed, based on responses to Round 3 interrogatories.

41) Interrogatory CR R315-101-5.3(6)-41/3: Table 7

DEQ Conclusion:

Closed, based on responses to Round 3 interrogatories.

42) Interrogatory CR R315-101-5.3(6)-42/1: Hazard Quotient in Tables 7 and 8

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

43) Interrogatory CR R313-25-19-43/1: Peak Dose in Table 11

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

44) Interrogatory CR R313-25-8(5)(a)-44/2: Occurrence of Intermediate Lakes

DEQ Conclusion:

Closed, based on DEQ's Round 3 critique of the Energy*Solutions* Round 2 response.

45) Interrogatory CR R313-25-7(2)-45/1: Inaccurate Cross-Reference

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

46) Interrogatory CR R313-25-7(1)-46/1: Tornados

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories.

47) Interrogatory CR R313-25-7(1)-47/1: Selection of Biome

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

48) Interrogatory CR R313-25-7(9)-48/3: Source and Composition of DU Waste

DEQ Conclusion:

Closed. The discussion is moot because Savannah River Site (SRS) DU waste will be excluded from disposal at Clive because it contains recycled uranium.

49) Interrogatory CR R313-25-7(9)-49/3: Composition of Material Mass

DEQ Conclusion:

Closed. The issues have been clarified in Energy*Solutions*' responses to Round 3 interrogatories.

50) Interrogatory CR R313-25-7(9)-50/3: Samples Collected

DEQ Conclusion:

Closed. The text is corrected in Appendix 4 to the DU PA Model v1.2, *Radioactive Waste Inventory for the Clive DU PA Model v1.2* (Neptune 2014e).

51) Interrogatory CR R313-25-7(9)-51/3: Nature of Contamination

DEQ Conclusion:

This interrogatory is closed because any license amendment will contain a license condition that disposal of recycled uranium is not allowed in the DU waste.

52) Interrogatory CR R313-25-7(9)-52/1: Measurement Types for Sampling Events

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories.

53) Interrogatory CR R313-25-7(9)-53/1: Subscripts in Equation 1

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

54) Interrogatory CR R313-25-7(9)-54/1: Partitioning in the Sensitivity Analysis

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

55) Interrogatory CR R313-25-8(5)(a)-55/2: Uranium Isotope Distributions

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

56) Interrogatory CR R313-25-7(9)-56/1: Interpretation of Box Plots

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

57) Interrogatory CR R313-25-7(9)-57/1: Dashed Lines in Figure 4

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

58) Interrogatory CR R313-25-7(9)-58/1: Reference for Personal Communication

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

59) Interrogatory CR R313-25-7(2)-59/2: Bathtub Effect

DEQ Conclusion:

Until the issues are resolved regarding the design of the cover and infiltration rates (see the DU PA SER, Section 4.1.1.1 and Appendix B) the potential for bathtubbing effects cannot be ruled out. Therefore, this interrogatory remains open.

60) Interrogatory CR R313-25-7(3)-60/2: Modeled Radon Barriers

DEQ Conclusion:

As described under Interrogatory 05, based on several unresolved issues related to the ET cover, DEQ indicated in the DU PA SER Section 4.1.1.1 that the cover design was deficient and that it cannot determine the adequacy of this portion of the Clive DU PA. (See the description under Interrogatory 05 for specific details.) Therefore, this interrogatory remains open.

61) Interrogatory CR R313-25-8(4)(a)-61/2: Mass-Balance Information

DEQ Conclusion:

The intent of Interrogatory 61 has been captured by Interrogatory 69, item 3. Interrogatory 61 is closed, and Interrogatory 69, item 3 should be consulted for the status of the Clive DU PA mass-balance concern.

62) Interrogatory CR R313-25-7(2)-62/2: Numerical Testing of Runge-Kutta Method

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

63) Interrogatory CR R313-25-8(4)(a)-63/2: Air-Phase Advection

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories.

64) Interrogatory CR R313-25-8(4)(a)-64/3: Yucca Mountain Studies

DEQ Conclusion:

Closed. As discussed in the DU PA SER (Section 4.1.4), given the inability of GoldSim to simulate the dependency of uranium solubility on kinetics and thermodynamics, the stochastic approach that was taken in the DU PA is judged to be acceptable.

65) Interrogatory CR R317-6-6.3(Q)-65/3: Colloid Transport

DEQ Conclusion:

Closed. As discussed in the DU PA SER (Section 4.1.4), colloids have been adequately addressed.

66) Interrogatory CR R313-25-8(4)(a)-66/2: Colloid Retention

DEQ Conclusion:

Closed. As discussed in the DU PA SER (Section 4.1.4), colloids have been adequately addressed.

67) Interrogatory CR R313-25-8(4)(a)-67/3: Solubility and Speciation of Radionuclides

DEQ Conclusion:

Closed. As discussed in the DU PA SER (Section 4.1.4), the solubility and speciation of radionuclides has been adequately addressed.

68) Interrogatory CR R313-25-8(4)(a)-68/2: Distribution of Hydraulic Gradients

DEQ Conclusion:

The DU PA SER (Section 6.2.7), Condition 7 states the following:

> *The Licensee shall develop and implement a program to provide more detailed hydrogeologic knowledge of the shallow unconfined aquifer and deeper confined aquifer…. Specific types of information include: groundwater flow velocities, aquifer transmissivities, water quality, sorption properties, and the degree of hydraulic interconnection between the upper and lower aquifers.*

Since such a program will be a requirement of any license amendment, the interrogatory is closed.

69) Interrogatory CR R313-25-8(4)(a)-69/2: Longitudinal Dispersivity

DEQ Conclusion:

Closed, based on responses to Round 3 interrogatories.

70) Interrogatory CR R313-25-7(2)-70/3: Gully Screening Model

DEQ Conclusion:

As noted in Section 4.4.2 of the DU PA SER:

> *Before the DU PA can be determined to be adequate, Energy*Solutions *needs to clarify certain issues relating to Appendix 10 to the DU PA v1.2 (June 5, 2014…) as described in Section 4.4.2. DRC is currently reviewing a license amendment request to use an ET cover of similar design to that proposed for the Federal Cell in the DU PA. Any recommendations and conclusions from that review must be applied to the proposed Federal Cell as well.*

Therefore, this interrogatory remains open.

71) Interrogatory CR R313-25-8(4)(a)-71/1: Biotic Processes in Gully Formation

DEQ Conclusion:

In its Round 1 response, Energy*Solutions* indicated that "*The mechanism of gully formation (e.g., burrowing animals, tree throw, OHV use, tornados) is not important in the function of the model, only that the gully exists*." The response continued: "*In the Clive DU PA Model v1.0, no such sophisticated analysis was done—rather, a simple distribution was used as a screening tool in order to determine whether gully formation would be a significant process at the site*." Energy*Solutions* concluded its response by stating that "*The thinner cover at gullies could also result in enhanced infiltration and enhanced radon flux from the wastes below, especially if the radon barrier were compromised*."

In Round 2, DEQ stated that the "*Round 1 Interrogatory Response is satisfactory, provided that the results of the SIBERIA modeling are reflected in the radon flux and other dose models*."

The Clive DU PA Model includes a gully formation model; however, the DU PA Model v1.2 (p. 3) states that "*No associated effects, such as biotic processes, effects on radon dispersion, or local changes in infiltration are considered within the gullies*." As indicated in the DU PA SER, Section 4.4.2, Energy*Solutions* offered the following explanation for these omissions in its Interrogatory 20 Round 2 response:

> *While the formation of some of the gullies may actually erode through significant depths of the evapotranspirative cover, the ratio of gully footprint to total evapotranspirative cover surface area remains minimal.*

Further, in its Round 3 response to Interrogatory 70, Energy*Solutions* stated that "*The influence of gully formation on infiltration and radon transport is negligible given the current below grade disposal design*." The reason given is "*that only a small fraction of the cover would have gullies extending through the surface and evaporative zone layers to the top of the frost protection layer*."

Nonetheless, the DU PA SER, Section 4.4.2 concluded the following:

> *Before the DU PA can be determined to be adequate, Energy*Solutions *needs to clarify certain issues relating to Appendix 10 to the DU PA Model v1.2 (…)... DRC is currently reviewing a license amendment request to use an ET cover of*

> *similar design to that proposed for the Federal Cell in the DU PA. Any recommendations and conclusions from that review must be applied to the proposed Federal Cell as well.*

Therefore, this interrogatory remains open.

72) Interrogatory CR R313-25-8(4)(a)-72/1: De Minimis Dose Value

DEQ Conclusion:

As stated in DEQ's Round 2 interrogatory, the text added by Energy*Solutions* to the DU PA Model v1.2, Section 3.3.3 satisfactory addressed this issue, and Interrogatory 72 is closed.

73) Interrogatory CR R313-25-19-73/1: ALARA Concept

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

74) Interrogatory CR R313-25-8(5)(a)-74/1: Tailored Discussion of Sensitivity Analysis

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

75) Interrogatory CR R313-25-7(9)-75/1: Branching Fractions

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

76) Interrogatory CR R313-25-7(10)-76/1: Quality Assurance Project Plan Signature Page

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories.

77) Interrogatory CR R313-25-7(10)-77/1: Quality Assurance Project Plan Page Numbering

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

78) Interrogatory CR R313-25-7(10)-78/2: GoldSim Model Calibration

DEQ Conclusion:

Clive DU PA Model calibration remains a concern. In its Round 1 response, Energy*Solutions* interpreted Interrogatory 78 to mean calibration against natural systems. However, DEQ believes that the GoldSim model can (and should) also be calibrated against other computer and/or mathematical models.

The Energy*Solutions* Round 1 response does indicate that the radon flux calculation was one area where the GoldSim model was calibrated against NRC Regulatory Guide (RG) 3.64 (NRC 1989). As indicated in DU PA SER Section 4.2, DEQ was not able to successfully duplicate the calibration of the Clive DU PA GoldSim radon model against the radon flux calculated using standard calculation procedures (i.e., RG 3.64). However, since the Clive DU PA model results in a conservative estimate of the radon flux, the DU PA SER determined it to be acceptable.

Interrogatory 90 requests information regarding infiltration rate calibration. The infiltration rate is dependent upon the functioning of the new ET cover design. As described under Interrogatory 05, based on several unresolved issues related to the ET cover, DEQ indicated in the DU PA SER, Section 4.1.1.1 that the cover design was deficient and that it cannot determine the adequacy of this portion of the Clive DU PA. See the description under Interrogatory 05 for the specific ET cover concerns and Interrogatory 90 for specifics regarding infiltration rate calibration.

In Round 2, DEQ requested "*documentation of any of the results of any 'global sensitivity analysis' that has been performed on the GoldSim DU PA model*." Energy*Solutions* responded by greatly expanding the sensitivity analyses provided in the DU PA Model v1.2, Appendix 15 (Neptune 2014d).

Because (1) Energy*Solutions* provided the requested "global sensitivity analysis" information, (2) the Clive DU PA Model is conservative with respect to , radon flux), and (3) other interrogatories (e.g., Interrogatories 05 and 90) address identical ET cover infiltration concerns, Interrogatory 78 is closed.

79) Interrogatory CR R313-25-7(10)-79/1: Critical Tasks and Schedule

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

80) Interrogatory CR R313-25-7(10)-80/2: Testing of GoldSim Abstractions

DEQ Conclusion:

This interrogatory is very similar to Interrogatory 78; see the response to Interrogatory 78. As for Interrogatory 78, because (1) the Clive DU PA Model is conservative (i.e., radon flux), and (2) other interrogatories (e.g., Interrogatories 05 and 90) address identical ET cover infiltration concerns, Interrogatory 80 is closed.

81) Interrogatory CR R313-25-7(2) and 7(6)-81/2: Comparison of Disposal Cell Designs

DEQ Conclusion:

Energy*Solutions* stated the following in its July 8, 2014, response to DEQ's Round 3 interrogatories:

> *A response to this Interrogatory was included in the Round 2 Interrogatory Response Report of June 17, 2014. Since no new findings or critique has been included with Round 3, nothing has been added to the original Round 2 response.*

DEQ does not agree with this statement.

In its Round 3 rebuttal, DEQ provided additional critique:

> *None of the ES* [Energy*Solutions*] *responses provided the requested comparison between the Class A West Cell and the Federal Cell cover designs. It is our belief that such a comparison of the structural design and expected performance of the cells with rock-armor and/or ET cover systems is needed to enable DRC to*

> *compare proposed and existing designs and ensure that the proposed designs comply with R313-25-7(2) and (6).*
>
> *At present, only a rock-armor cover system has been approved for the Class A West cell, and the proposed ET cover system for that cell is undergoing DRC review and has not yet been approved. ES should compare the proposed Federal Cell with all alternative cover systems that have been proposed for the Class A West cell, or with an approved cover system only.*
>
> *The proposed Federal Cell that contains the DU waste must have an approved design such that its cover system is fully integrated with, or completely isolated from, the existing 11e.(2) cover system, as appropriate, based on applicable federal and state laws and regulations. ES should show how the proposed ET cover system, based on soil, will be integrated with, or isolated from, the existing 11e.(2) rock-armor cover system. ES should describe how the design of that part of the Federal Cell containing DU waste will meet all potentially applicable DOE* [U.S. Department of Energy] *and NRC regulations, including types of wastes disposed of and connection, or lack of connection, with nearby waste cells, and also types of influence, or lack of influence, on or by other nearby waste cells, including the existing 11e.(2) cell.*
>
> *At this time, DRC does not expect ES to provide a "stand-alone engineering design report," as was requested in the original interrogatory. However, a more complete description of structural design and performance is requested, particularly in the design of features of the proposed cell contrasting with features of existing cells. We look forward to reviewing the revised information.*

Energy*Solutions* did not, for example, provide any information about how the DU portion and the 11e.(2) portion of the Federal Cell would be linked or segregated. As discussed in the DU PA SER, Section 6.2.4:

> *To meet the requirements of UAC R313-25-9(5)(a), Energy*Solutions *shall submit a revised performance assessment that meets the requirements of that provision and that addresses the total quantities of concentrated DU and other wastes, including wastes already disposed of and the quantities of concentrated DU the facility now proposes to dispose in the Federal Cell.*

In addition, as stated Section 6.1.3 of the DU PA SER:

> *DRC is currently reviewing a license amendment request to use an ET cover of similar design to that proposed for the Federal Cell in the DU PA. Any recommendations and conclusions from that review must be applied to the proposed Federal Cell as well.*

These DU PA SER requirements should provide sufficient analyses and data to remedy the shortcomings of the Energy*Solutions* response to this interrogatory. Subsequently, Energy*Solutions* has advised that the proposed Federal Cell will be physically separated from the 11e.(2) cell. Energy*Solutions* has provided only engineering drawings but no written description of the new cell (i.e., Appendices 3 and 16 to the DU PA have not been revised). In addition, no information has been provided on the function of the 1-foot liner protective cover shown in Drawing No. 14002-L1A(0). What material is used? Was it included in performance assessment analyses? Therefore, this interrogatory remains open.

82) Interrogatory CR R313-25-20-82/2: Limitation on Inadvertent Intruder Scenarios

DEQ Conclusion:

Closed. See Interrogatory CR R313-25-8(4)(b)-07/2: Applicability of NRC Human Intrusion Scenarios.

83) Interrogatory CR R313-25-20-83/2: Intruder-Driller and Natural Resource Exploration Scenarios

DEQ Conclusion:

Closed. See Interrogatory CR R313-25-8(4)(b)-07/2: Applicability of NRC Human Intrusion Scenarios.

84) Interrogatory CR R313-25-7(6)-84/3: Below-Grade Disposal of DU

DEQ Conclusion:

As noted in Sections 4.1.1.1, 4.1.1.3, and 4.4 of the DU PA SER, several issues regarding the ET cover remain unresolved. Therefore, this interrogatory remains open.

85) Interrogatory CR R313-25-8(4)(a)-85/1: Uncertainty Distributions Assigned to Dose Conversion Factors

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

86) Interrogatory CR R313-25-8(5)(a)-86/3: Consequences of Sedimentation on Disposal Cell

DEQ Conclusion:

Because the DU will be disposed of below the current ground surface, uncovering the DU by wave-cutting is not considered realistic. For this reason and the reasons given under Interrogatory 18, Interrogatory 86 is closed.

87) Interrogatory CR R315-101-5.3(6)-87/2: Oral Toxicity Parameters

DEQ Conclusion:

The U.S. Environmental Protection Agency (EPA) is reviewing the uranium reference dose for ingestion (RfD) from the Integrated Risk Information System (IRIS) program, which is the higher of the two values used in the DU PA. If only the EPA RfD based on the drinking water maximum contaminant level (MCL) had been used, the calculated hazard indices would be lower, indicating that the DU PA approach is not conservative. However, since the calculated hazard indices are so small—on the order of 10^{-10} to 10^{-11} (see Neptune 2014a, Table 6), reliance on the RfD based only on the drinking water MCL for uranium would not change the conclusion that uranium oral toxicity is not an issue. Therefore, this interrogatory is closed.

88) Interrogatory CR R313-25-20-88/2: Collective Dose and ALARA

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

89) Interrogatory CR R313-25-7(9)-89/3: Contamination Levels in DUF6

DEQ Conclusion:

Closed, because any license amendment will contain a condition that recycled uranium will not be permitted in DU waste.

90) Interrogatory CR R313-25-7(1–2)-90/2: Calibration of Infiltration Rates

DEQ Conclusion:

As noted in Sections 4.1.1.1, 4.1.1.3, and 4.4 of the DU PA SER, several issues (including infiltration rates) regarding the ET cover remain unresolved. Therefore, this interrogatory remains open.

91) Interrogatory CR R313-25-7(2)-91/1: Design Criteria for Infiltration

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

92) Interrogatory CR R313-25-20-92/2: Inadvertent Intruder Dose Standard and Scenarios

DEQ Conclusion:

Closed. See Interrogatory CR R313-25-8(4)(b)-07/2: Applicability of NRC Human Intrusion Scenarios. In addition, note that DEQ has made a policy decision that 500 millirem per year (mrem/yr) total effective dose equivalent is the appropriate dose standard for inadvertent intrusion.

93) Interrogatory CR R313-25-22-93/2: Stability of Disposal Site after Closure

DEQ Conclusion:

The interrogatory requested that Energy*Solutions*:

1. Include long-term performance analysis for a scenario where wave-cut action from a pluvial lake breaches the proposed Federal Cell cover system and DU waste. Alternatively, redesign the Proposed Federal Cell to locate the DU waste and its overlying radon barrier at an elevation that is below the native ground surface.
2. Revise the consideration of the span of time used in the performance assessment modeling to go beyond the time period for which the disposal embankment maintains its designed condition and function, and explain and justify why the span of time used in the performance assessment modeling for engineering design requirements was adequate to comply with the requirements of UAC R313-25-8(4) and (5).

Regarding item 1, the proposed Federal Cell has been redesigned to locate the DU waste below natural grade. Regarding item 2, Energy*Solutions* has performed a DTSA (Neptune 2014b, 2015a) reflecting radionuclide exposures beyond 10,000 years for the redesigned Federal Cell with below-grade DU exposure. The DEQ's evaluation of the DTSA is provided in Section 5.1.1 of the DU PA SER.

Thus, this interrogatory is considered to be closed, and Section 5.1.1 of the DU PA SER should be consulted for concerns identified during DEQ's review of the DTSA.

94) Interrogatory CR R313-25-3(8)-94/1: Ultimate Site Owner

DEQ Conclusion:

The Energy*Solutions* Round 1 interrogatory response is satisfactory. Condition 1 in Section 6.2.1 of the DU PA SER specifies that:

> *Energy*Solutions *shall provide a written agreement letter between DOE and Energy*Solutions *that:*
>
> a) *Includes Energy*Solutions*' agreement to convey and DOE's agreement to accept, after decommissioning, ownership of that portion of Energy*Solutions*' facility on which concentrated DU has been land disposed;*
>
> b) *Is enforceable by DEQ even if Energy*Solutions *no longer exists; and*
>
> c) *Has been approved by the Governor of the State of Utah.*

Based on the proposed license condition, this interrogatory is closed.

95) Interrogatory CR R313-25-8(4)(a)-95/2: Estimation of I-129 Concentrations

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

96) Interrogatory CR R313-25-8(4)(a)-96/3: Current and Future Potability of Water

DEQ Conclusion:

Scenarios discussed in Section 4.2.2 of the DU PA SER show that exposures to individuals from water rendered potable by reverse osmosis are well within acceptable limits for both inadvertent intruders and members of the public. Therefore, this interrogatory is closed.

97) Interrogatory CR R313-25-8(4)(a)-97/3: Need for Potable and/or Industrial Water

DEQ Conclusion:

As discussed in Section 4.2.2 of the DU PA SER, Energy*Solutions* evaluated a dust-suppression scenario in which a worker was exposed via the inhalation pathway for 2,000 hours per year. The annual dose was less than 10^{-6} mrem/yr. Therefore, this interrogatory is closed.

98) Interrogatory CR R313-25-7(1)-98/1: Monthly Temperatures

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories.

99) Interrogatory CR R313-25-7(1)-99/1: Evaporation

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

100) Interrogatory CR R313-25-7(1)-100/2: Groundwater Recharge from Precipitation

DEQ Conclusion:

As noted in Sections 4.1.1.1, 4.1.1.3, and 4.4 of the DU PA SER, several issues (including recharge) regarding the ET cover remain unresolved. Therefore, this interrogatory remains open.

101) Interrogatory CR R313-25-7(1)-101/2: Nature of Units 1 and 2

DEQ Conclusion:

Although Energy*Solutions* has provided additional information in the conceptual site model for disposal of DU at the Clive site (Neptune 2014c), an aspect of the hydrogeologic system that has not been explained is the cause of the shallow groundwater mounding in the vicinity of Wells MW-60 and MW-63 in the southern part of Section 32 and potential impacts throughout time on vertical components of hydraulic gradient. A general requirement for the collection of additional hydrogeologic information is discussed in the DU PA SER (Section 6.2.7) under Condition 7, which states that "*the Licensee shall develop and implement a program to provide more detailed hydrogeologic knowledge of the shallow unconfined aquifer and deeper confined aquifer…. Specific types of information include: groundwater flow velocities, aquifer transmissivities, water quality, sorption properties, and the degree of hydraulic interconnection between the upper and lower aquifers*."

Based on the proposed license condition, this interrogatory is closed.

102) Interrogatory CR R313-25-7-102/1: Seismic Activity

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

103) Interrogatory CR R313-25-7-103/2: Historical Flooding

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories.

104) Interrogatory CR R313-25-7(2)-104/3: Infiltration in the Presence of Rip Rap or Natural Rock

DEQ Conclusion:

Closed. This interrogatory is no longer relevant because the proposed Federal Cell will use an ET cover.

105) Interrogatory CR R313-25-8(4)(a)-105/3: Human Use of Groundwater

DEQ Conclusion:

As discussed in Section 4.2.2 of the DU PA SER, Energy*Solutions* evaluated a well-drilling scenario, which demonstrated that exposure to the inadvertent intruder was very low, with annual doses being less than 10^{-6} mrem/yr). Therefore, this interrogatory is closed.

106) Interrogatory CR R313-25-8(4)(a)-106/3: Desalination Potential

DEQ Conclusion:

As discussed in Section 4.2.2 of the DU PA SER, modeling studies show that doses associated with the use desalinated water are small. In addition, as noted in Section 6.1.2 of the DU PA SER: "*a characterization program needs to be established to gain a better understanding of the spatial and temporal characteristics of the hydrogeologic system, particularly as related to the lower aquifer*." In particular, additional onsite and near-site information that will be needed for investigating the hydrogeology of the deeper gravel zones of the confined aquifer include hydraulic heads, hydraulic conductivities, hydraulic gradients, connectivity with the upper aquifer, and water quality. Based on the proposed license condition, this interrogatory is closed.

107) Interrogatory CR R313-25-7(1)-107/2: Predominant Vegetation at the Clive Site

DEQ Conclusion:

Closed, based on responses to Round 3 interrogatories and review of revised text.

108) Interrogatory CR R313-25-8(4)(a)-108/2: Biointrusion

DEQ Conclusion:

As discussed in the DU PA SER (Section 4.4.3), Energy*Solutions* has not shown that the cover system is sufficiently thick or designed with adequate materials to protect the cover system or the underlying bulk waste in the embankments against deep rooting by indigenous greasewood (a species known to penetrate soils at other sites down to 60 feet) or other plants, or against biointrusion by indigenous ants or mammals (e.g., with maximum documented burrowing depths greater than the proposed cover thickness). Higher rates of infiltration are typically associated with higher contaminant transport rates. Moreover, burrowing and rooting into bulk waste in the space below the cover system and above the DU may allow for transport of radioactive contaminants to the surface. If no bulk waste is emplaced, then this would not be an issue. However, since the economics of filling the space with non-radioactive soil versus LLRW are extremely negative, it is HIGHLY unlikely that the Licensee would do that. It is reasonably anticipated that this space would be filled with LLRW. The Licensee has dismissed the need to model such transport. Accordingly, DEQ has concerns about the thickness of the cover system. Under Utah rules, infiltration should be minimized [see UAC Rule R313-25-25(3) and (4)]. DEQ cannot determine the adequacy of the DU PA until Energy*Solutions* accounts for greater potential infiltration through the cover system at the proposed Federal Cell embankment due to biointrusion by plant roots and by animals. Therefore, this interrogatory remains open.

109) Interrogatory CR R313-25-7(2)-109/1: Geochemical Degradation of Rip Rap

DEQ Conclusion:

Energy*Solutions* noted in its Round 2 interrogatory response that:

> *Additionally, the current LLRW and 11e.(2) CQA/QC Manual - Rock Erosion Barrier Work Element includes Quality of Rock controls that mirror WJE's recommendation for selection of material that "would be less prone to relatively rapid deterioration that has reportedly occurred relatively soon after the material was installed." Finally, the results of the DOE and WJE studies further demonstrate that the weathered rock observed on the Vitro and LARW covers is limited to a small percentage of the overall rock covering (less than 1%) and are not expected to increase in the geologic short term.*

Application of the Rock Barrier Work Element in the *LLRW* [Low-Level Radioactive Waste] *and 11e.(2) CQA/QC* [Construction Quality Assurance/Quality Control] *Manual* (ES 2012) to any rip rap used on the side slopes of the proposed Federal Cell should minimize the potential for degradation. Therefore, this interrogatory is closed.

110) Interrogatory CR R313-25-8(4)(a)-110/1: Radon Transfer from Water

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

111) Interrogatory CR R313-25-7-111/2: Likelihood of Lava Dam Formation

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories.

112) Interrogatory CR R313-25-8(4)(a)-112/2: Hydraulic Conductivity

DEQ Conclusion:

As discussed in the DU PA SER (Section 4.1.1.1), there are still a number of unresolved issues with respect to the selection of parameter ranges, distributions, and correlations, as well as the modeling approach and predicted sensitivities. These concerns are detailed in Appendix B to the DU PA SER. Therefore, this interrogatory remains open.

113) Interrogatory CR R313-25-8(5)(a)-113/2: Placement of Bulk Low-Level Waste among DU Canisters

DEQ Conclusion:

Based on the Section 6.2.4 of the DU PA SER, Energy*Solutions* must complete and DEQ must approve a performance assessment that includes DU <u>and other wastes</u> before the land disposal of other radioactive wastes in the Federal Cell can commence. Approval of the DU PA will include this requirement. Therefore this interrogatory is closed.

114) Interrogatory CR R313-25-19-114/3: Elevated Concentrations of Tc-99

DEQ Conclusion:

As stated in Section 6.1.2 of the DU PA SER:

> ***Compliance with Groundwater Protection Levels [UAC-R317-6-4]*** *– Because there is significant uncertainty regarding the Tc-99 concentration in the* DU_3O_8 *to be produced from the GDP* [gaseous diffusion plant] *tailings, and because Tc-99* [technetium-99] *and other mobile isotopes may exceed the GWPL* [groundwater protection level] *at 500 years, DEQ has determined that all issues related to this portion of the DU PA have been resolved with the condition that no DU waste containing recycled uranium be accepted for disposal inside the Federal Cell at Clive.*

Based on the assumption that disposal of recycled uranium will not be permitted in the proposed Federal Cell, this interrogatory is closed.

115) Interrogatory CR R315-101-5.3(6)-115/1: Uranium Toxicity Reference Doses

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories.

116) Interrogatory CR R313-25-8(4)(a)-116/1: Cs-137 Decay

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories.

117) Interrogatory CR R313-25-8(5)(a)-117/2: Groundwater Protection Limit for Tc-99

DEQ Conclusion:

As stated in Section 6.1.2 of the DU PA SER:

> ***Groundwater Protection Levels*** *– Because there is significant uncertainty regarding the Tc-99 concentration in the* DU_3O_8 *to be produced from the GDP tailings, and because Tc-99 and other mobile isotopes may exceed the GWPL at 500 years, DEQ has determined that all issues related to this portion of the DU PA have been resolved with the condition that no DU waste containing recycled uranium be accepted for disposal inside the Federal Cell at Clive.*

Based on the assumption that disposal of recycled uranium will not be permitted in the proposed Federal Cell, this interrogatory is closed.

118) Interrogatory CR R313-25-7(10)-118/1: GoldSim Results

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

119) Interrogatory CR R313-25-8(4)(a)-119/1: Resuspension and Airborne Pathways

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

120) Interrogatory CR R313-25-8(4)(a)-120/3: Gullies and Radon

DEQ Conclusion:

In its Round 3 response to Interrogatory 120, Energy*Solutions* refers to its Interrogatory 70 response, in which it states that "*The influence of gully formation on infiltration and radon transport is negligible given the current below grade disposal design*." The reason given is "*that only a small fraction of the cover would have gullies extending through the surface and evaporative zone layers to the top of the frost protection layer*." Coupled with the extreme depth at which the DU is buried, this implies that gully formation would not affect radon transport.

As indicated in the DU PA SER, Section 4.2.1, DEQ was not able to successfully duplicate the calibration of the Clive DU PA GoldSim radon model against the radon flux calculated using standard calculation procedures (i.e., RG 3.64). In Section 4.2.1, DEQ showed that the Clive DU PA Model takes little credit for radon attenuation by the ET cover; rather, most of the radon attenuation is provided by the material (e.g., non-DU waste) lying between the DU and the ET cover. Since the ET cover is being credited for very limited radon attenuation in the Clive DU PA Model v1.2, gullies that reduce the thickness of the ET cover would not greatly affect the resulting ground surface radon flux. See Table 4-4 of DU PA SER. Therefore, the DU PA SER determined that the Clive DU PA Model v1.2 radon flux calculation is conservative and thus acceptable. Consequently, this interrogatory is closed.

121) Interrogatory CR R313-25-19-121/2: Gullies and Receptor Location

DEQ Conclusion:

Even though Interrogatory 121 explicitly states that it has "*to do with the OHV enthusiast dose model*," the Energy*Solutions* Round 2 response focuses instead on groundwater concentrations. As such, the Energy*Solutions* Round 2 response to Interrogatory 121 does not respond to the actual interrogatory.

Nevertheless, in DU PA SER, Section 4.2.1, DEQ showed that the Clive DU PA Model v1.2 takes little credit for radon attenuation by the ET cover. Also, as demonstrated by the DU PA Model v1.2, Appendix 15(II), Table 5, about 77.5 percent of the off-highway vehicle (OHV) enthusiast's dose is accounted for by the radon escape/production ratio, which would not be affected by gully formation (Neptune 2014d). Finally, as shown in the DU PA Model v1.2, Table ES-1 (Neptune 2014a), the Clive DU PA v1.2 calculated OHV enthusiast's dose is small and would need to be raised by several orders of magnitude before it approaches the intruder dose limit.

Disregarding the Energy*Solutions* Round 2 response, DEQ has found that Interrogatory 121 may be considered closed for the purpose of the DU PA Model v1.2 evaluation.

122) Interrogatory CR R313-25-8(4)(d)-122/2: Size of Pluvial Lakes

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

123) Interrogatory CR R313-25-8(4)(d)-123/2: Timing of Lake Cycles

DEQ Conclusion:

DEQ's expert concurs (Bradley 2014) with the Energy*Solutions* assumption regarding the return timing of the first Intermediate Lake provided in the DTSA (Neptune 2014b, 2015a). Therefore, this interrogatory is closed.

124) Interrogatory CR R313-25-8(4)(d)-124/2: Mechanisms for Pluvial Lake Formation

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

125) Interrogatory CR R313-25-8(4)(d)-125/2: Deep Lake Cycles

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

126) Interrogatory CR R313-25-8(4)(d)-126/2: Shallow Lake Cycles

DEQ Conclusion:

Closed, based on the discussions under Interrogatories 44 and 132.

127) Interrogatory CR R313-25-8(4)(d)-127/2: Carbonate Sedimentation

DEQ Conclusion:

Closed, based on DEQ's Round 3 critique of the Energy*Solutions* Round 1 response and the revisions made in the DU PA Model v1.2.

128) Interrogatory CR R313-25-8(4)(d)-128/2: Lake Sedimentation

DEQ Conclusion:

For all intents and purposes, the concerns raised in this interrogatory duplicate the concerns raised in Interrogatory 18. The Interrogatory 18 evaluation is equally applicable to this interrogatory. Since they are essentially duplicates, Interrogatory 128 may be closed and its concerns addressed under Interrogatory 18.

129) Interrogatory CR R313-25-8(4)(d)-129/2: Lake Erosion

DEQ Conclusion:

In its Round 1 response, Energy*Solutions* detailed the assumptions pertaining to the deep time erosion of the embankment and obliteration of the disposal site through wave action. DEQ agreed with the Energy*Solutions* response but recommend that the final report discuss a DTSA, which expands on the information provided in the Energy*Solutions* response.

As indicated in the evaluation of several interrogatories, Energy*Solutions* has provided a DTSA (Neptune 2014b, 2015a), which makes the original DU PA Model v1.0 and v1.2 deep time analyses obsolete.

For these reasons, plus the fact that its concerns are subsumed in other deep time interrogatories (e.g., Interrogatories 18, 86, and 159), Interrogatory 129 is closed.

130) Interrogatory CR R313-25-8(4)(d)-130/1: Lake Geochemistry

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

131) Interrogatory CR R313-25-8(4)(d)-131/2: Potential Wave Energy

DEQ Conclusion:

The DU will be disposed of below the current ground surface; thus, uncovering the DU by wave-cutting is not considered realistic. Also, the DTSA (Neptune 2014b) assumed that the embankment would be destroyed by the first lake to reach Clive; the potential wave energy of the large or small lake would not change the results of the Clive DU PA Model. As such, this interrogatory is considered to be editorial, i.e., simply a request for clarification of the text. Thus, Interrogatory 131 is closed.

132) Interrogatory CR R313-25-8(4)(d)-132/2: Sedimentation Model

DEQ Conclusion:

In its Round 3 responses to Interrogatories 03 and 86, Energy*Solutions* indicated that a revised deep time model had been developed that took into account aeolian deposition, as well as lake sedimentation. The results of applying the revised model were provided to DEQ in the DTSA (Neptune 2014b, 2015a). While the DTSA incorporated the revised aeolian deposition model, the lake sediment model was identical to that used in the DU PA Model v1.0 and v1.2 (Neptune 2011, 2014a). In the DU PA SER, Section 5.1.1, DEQ evaluated the DTSA and, while agreeing with the revised aeolian deposition distribution, expressed concern regarding the magnitude of the Intermediate Lake sedimentation rate, among other areas of concern. DEQ performed GoldSim analyses to investigate its concerns and calculated radon fluxes that were significantly greater than the DTSA-reported flux.

Since the revised DTSA provided by Energy*Solutions*/Neptune does not address DEQ concerns regarding the large Intermediate Lake sedimentation rate, DEQ believes that there are still open questions related to ground surface radon fluxes reported in the revised DTSA (Neptune 2015a). Therefore, based upon our current understanding of the uncertainties contained within the deep time analysis, DEQ/SC&A is unable to determine at this time that the DTSA portion of the DU PA Model v1.2 is satisfactory, and Interrogatory 132 remains open.

133) Interrogatory CR R313-25-8(4)(d)-133/2: Calculations of Radioactivity in Water and Sediment

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

134) Interrogatory CR R313-25-8(4)(d)-134/1: Future Lake Level Elevations

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

135) Interrogatory CR R313-25-19-135/3: Exposure to Groundwater

DEQ Conclusion:

As discussed in Section 4.2.2 of the DU PA SER, modeling studies show that doses associated with the use of desalinated water are small. Therefore, this interrogatory is closed.

136) Interrogatory CR R313-25-7(1)-136/2: Iron (Hydro)Oxide Formation

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

137) Interrogatory CR R313-25-7(1)-137/2: Total Dissolved Carbonate Concentrations and Other Geochemical Data

DEQ Conclusion:

Closed. As discussed in the DU PA SER (Section 4.1.4), the impact of total dissolved carbonate on solubilities has been adequately addressed.

138) Interrogatory CR R313-25-26(1)-138/3: Monitoring Well Completion Zones

DEQ Conclusion:

Closed, based on responses to Round 3 interrogatories and review of revised text.

139) Interrogatory CR R313-25-7(1)-139/2: Ion Charge Balance

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

140) Interrogatory CR R313-25-7(1)-140/2: Determination of Kd Values

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

141) Interrogatory CR R313-25-7(1)-141/2: pH and Kd Values and Serne (2007)

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

142) Interrogatory CR R313-25-7(1)-142/2: References for Kd Discussion

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

143) Interrogatory CR R313-25-7(1)-143/2: Neptunium Speciation

DEQ Conclusion:

Closed. As discussed in the DU PA SER (Section 4.1.4), neptunium speciation has been adequately addressed.

144) Interrogatory CR R313-25-7(1)-144/2: Plutonium Speciation

DEQ Conclusion:

Closed. As discussed in the DU PA SER (Section 4.1.4), plutonium speciation has been adequately addressed.

145) Interrogatory CR R313-25-7(1)-145/2: Sorption Reversibility and Glover et al. (1976) Dataset

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

146) Interrogatory CR R313-25-7(1)-146/2: Determination of Kd Values

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

147) Interrogatory CR R313-25-7(1)-147/2: Determination of Kd Value for Uranium

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

148) Interrogatory CR R313-25-7(1)-148/2: Influence of Carbonate on Uranium Speciation

DEQ Conclusion:

Closed. As discussed in the DU PA SER (Section 4.1.4), the influence of carbonate on uranium speciation has been adequately addressed.

149) Interrogatory CR R313-25-7(1)-149/2: Americium Sorption

DEQ Conclusion:

Closed, based on responses to Round 2 interrogatories and review of revised text.

150) Interrogatory CR R313-25-7(2)-150/3: Plant Growth and Cover Performance

DEQ Conclusion:

As discussed in the DU PA SER (Section 4.4.3), concerns remain regarding the potential impacts of biointrusion on infiltration.

151) Interrogatory CR R313-25-8(4)(a)-151/2: Radon Barrier Attenuation

DEQ Conclusion:

As indicated in DU PA SER, Section 4.2.1, DEQ was not able to successfully duplicate the calibration of the Clive DU PA GoldSim radon model against the radon flux calculated using standard calculation procedures (i.e., RG 3.64). Specifically, the Energy*Solutions* Round 3 response stated that "*the effective diffusion coefficient is calculated as the product of the diffusion coefficient in free air and the tortuosity*"—implying that the diffusion coefficient is inversely, linearly proportional to the moisture content of the waste. However, the commonly accepted Rogers and Neilson (1991) relationship has the diffusion coefficient inversely proportional to the exponential of the moisture content of the waste raised to a power, as pointed out in the DU PA SER, Section 4.2.1. For the radon barrier layer, which is designed to hold moisture, this difference in the calculating of the diffusion coefficient is particularly important.

However, since the Clive DU PA model results in a conservative estimate of the radon flux, the DU PA SER determined it to be acceptable. Therefore, this interrogatory is closed.

152) Interrogatory CR R313-25-8(5)(a)-152/2: GoldSim Input Parameters

DEQ Conclusion:

As indicated in the DU PA SER, Section 4.2.1, DEQ was not able to successfully duplicate the calibration of the Clive DU PA GoldSim radon model against the radon flux calculated using standard calculation procedures (i.e., RG 3.64), with or without applying the radon correction factors (RnDiffusivityCorrection). However, since the Clive DU PA model results in essentially the same ground surface radon flux as was calculated by DEQ/SC&A, the DU PA SER determined it to be acceptable. Therefore, this interrogatory is closed.

153) Interrogatory CR R313-25-8(4)(d)-153/2: Impact of Pedogenic Process on the Radon Barrier

DEQ Conclusion:

The focus of Interrogatory 153 is on the impact of pedogenic processes with respect to effects on hydraulic conductivity of the ET cover. As described under Interrogatory 05, based on several unresolved issues related to the ET cover (including issues related to the selection of parameter values, ranges, and correlations), DEQ indicated in the DU PA SER, Section 4.1.1.1 that the cover design was deficient and that it cannot determine the adequacy of this portion of the Clive DU PA. (See the description under Interrogatory 05 for the specific details.) Therefore, this interrogatory remains open.

154) Interrogatory CR R313-25-8(4)(d)-154/2: Use of Field Data to Validate Disposal Cell Cover Performance

DEQ Conclusion:

For the reasons given under Interrogatory 27, Interrogatory 154, as it applies to radon diffusion, is closed.

155) Interrogatory CR R313-25-8(4)(d)-155/3: Cover Performance for 10,000 Years

DEQ Conclusion:

For the reasons given under Interrogatory 27, Interrogatory 155, as it applies to radon diffusion, is closed.

156) Interrogatory CR R313-25-26(2–3)-156/3: Separation of Wastes in Federal Cell

DEQ Conclusion:

Condition 1 in Section 6.2.1 of the DU PA SER specifies that:

> *Energy*Solutions *shall provide a written agreement letter between DOE and* *Energy*Solutions *that:*

> a) *Includes Energy*Solutions*' agreement to convey and DOE's agreement to accept, after decommissioning, ownership of that portion of Energy*Solutions*' facility on which concentrated DU has been land disposed;*
>
> b) *Is enforceable by DEQ even if Energy*Solutions *no longer exists; and*
>
> c) *Has been approved by the Governor of the State of Utah.*

Based on that condition being met, the interrogatory is closed.

157) Interrogatory CR R313-25-8(5)(a)-157/2: Inclusion of DU and Other Wastes in PA

DEQ Conclusion:

Energy*Solutions* states in its response to the Round 2 interrogatories:

> *As is reported in the Condition 35 Compliance Report and version 1.2 of the Modeling Report, Energy*Solutions *has committed not to dispose of any "other wastes" in the Federal Cell until a Performance Assessment can be compiled that includes both DU and other Class A wastes. Until that time, Energy*Solutions *will only dispose of depleted uranium waste below grade in the Federal Cell. As such, the waste inventory included in version 1.2 of the Modeling Report is representative of all wastes currently projected to be disposed of in the Federal Cell.*

Further, as noted in Section 6.2.4 of the DU PA SER, Condition 4 for approval of the DU PA specifies that:

> *To meet the requirements of UAC R313-25-9(5)(a), Energy*Solutions *shall submit a revised performance assessment that meets the requirements of that provision and that addresses the total quantities of concentrated DU and other wastes, including wastes already disposed of and the quantities of concentrated DU the facility now proposes to dispose in the Federal Cell. This revised performance assessment shall be subject to notice and comment and must be approved by the Director prior to the land disposal of significant quantities of other radioactive wastes.*

Given the Energy*Solutions* requirement to analyze other wastes and the condition for approval in the DU PA SER, this interrogatory is closed.

158) Interrogatory CR R313-15-1009(2)(b)(i)-158/2: Waste Packaging

DEQ Conclusion:

This issue was adequately addressed in the Energy*Solutions* Round 2 response. It is judged to be a relevant operational concern but it is not relevant to approval of the DU PA. Therefore, this interrogatory is closed.

159) Interrogatory CR R313-25-8(4)(d)-159/2: Embankment Damage by Lake Formation

DEQ Conclusion:

For the reasons provided under Interrogatories 18 and 132, Interrogatory 159 is closed.

160) Interrogatory CR R313-25-7(2)-160/2: Comparison of Class A West and Federal Cell Designs

DEQ Conclusion:

Energy*Solutions* stated the following in its response to Round 2 interrogatories:

> *Version 1.2 of the Modeling Report has been revised to reflect the construction of an evapotranspirative cover over the proposed Federal Cell. While Energy*Solutions *recognizes that it is seeking separate approval for construction of a similar cover system over its Class A West (CAW) embankment from the Division, demonstration of the CAW cover's ability to satisfy low-level radioactive waste disposal performance objectives unique to Class A-type waste are unrelated to the requirements imposed on the Federal Cell evapotranspirative cover's ability to satisfy the unique depleted uranium performance criteria addressed in version 1.2 of the Modeling Report.*

DEQ does not agree with the Energy*Solutions* statement that demonstration of the CAW cover's ability to satisfy low-level radioactive waste disposal performance objectives unique to Class A-type waste are unrelated to the requirements imposed on the proposed Federal Cell ET cover's ability to satisfy the unique DU performance criteria addressed in DU PA Model v1.2. DU is a Class A waste. Both cells must contain Class A waste for extended periods of time—a factor of about 10 longer for the proposed Federal Cell.

As stated in Section 4.4.2 of the DU PA SER:

> *Before the DU PA can be determined to be adequate, Energy*Solutions *needs to clarify certain issues relating to Appendix 10 to the DU PA Model v1.2 (June 5, 2014…) as described in Section 4.4.2. DRC is currently reviewing a license amendment request to use an ET cover of similar design to that proposed for the Federal Cell in the DU PA. Any recommendations and conclusions from that review must be applied to the proposed Federal Cell as well.*

Therefore, this interrogatory remains open.

161) Interrogatory CR R313-25-7(2–3)-161/3: Inconsistent Information on Waste Emplacement

DEQ Conclusion:

In its Round 1 response, Energy*Solutions* committed to bury only that volume of DU waste that can be accommodated below grade. Energy*Solutions* revised Figure 9 in Appendix 3 to the DU PA Model v1.2 (Neptune 2014f) to show the waste layering adopted for version 1.2 of the Clive DU PA Model. The available information is sufficient to make decisions as to the adequacy of the DU PA. Additional specifics with regard to waste emplacement will be required in any license application request. Therefore, this interrogatory is closed.

162) Interrogatory CR R313-25-22-162/2: Disposal Cell Stability

DEQ Conclusion:

As stated in Section 4.4.2 of the DU PA SER:

> *Before the DU PA can be determined to be adequate, Energy*Solutions *needs to clarify certain issues relating to Appendix 10 to the DU PA Model v1.2 (June 5, 2014…) as described in Section 4.4.2. DRC is currently reviewing a license amendment request to use an ET cover of similar design to that proposed for the Federal Cell in the DU PA. Any recommendations and conclusions from that review must be applied to the proposed Federal Cell as well.*

Therefore, this interrogatory remains open.

163) Interrogatory CR R313-25-8(5)(a)-163/3: Groundwater Compliance for 10,000 Years

DEQ Conclusion:

Several groundwater pathways were examined in the DU PA SER, Section 4.2.2. In every case, doses were small. Therefore this interrogatory is closed.

164) Interrogatory CR R313-15-1009-164/1: Incorrect Rule Citation

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

165) Interrogatory CR R313-15-1009(1)(c)(i)-165/1: Incorrect Citation of Ra-226 Limit

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories and review of revised text.

166) Interrogatory CR R313-25-22-166/2: Stability of Waste

DEQ Conclusion:

As discussed in Section 4.1.1.2 of the DU PA SER, a test pad to demonstrate that void spaces within the DU waste disposal cylinders and between the disposal cylinders can be effectively eliminated may be required, unless Energy*Solutions* can provide adequate information that the waste cylinders and waste lifts can be fully backfilled. However, this is an issue to address in any license amendment rather than as an integral element in approval of the DU PA. Therefore, this interrogatory is closed.

167) Interrogatory CR R313-15-1009(2)(a)(vii)-167/1: Pyrophoricity of DUO_2

DEQ Conclusion:

The Energy*Solutions* response in satisfactory and the interrogatory is closed.

168) Interrogatory CR R313-25-7(2)-168/1: Rip Rap Sizing

DEQ Conclusion:

Energy*Solutions* stated in response to Round 2 interrogatories that:

> *As is reflected in Section 3.1.2 of Appendix 3 – Embankment Modeling to version 1.2 of the Modeling Report (attached as Appendix A to the Compliance Report), there is no riprap material included in the construction of the proposed evapotranspirative cover. No changes in the Division-approved riprap specifications for EnergySolutions' current drainage ditch network is required as*

> *a result of approval of the Federal Cell. Approved riprap specifications are summarized in Figure 6 of Appendix 3.*

This response is satisfactory and this interrogatory is closed.

169) Interrogatory CR R313-25-7(9)-169/3: Clarification of Statistical Treatment of Chemical and Isotopic Assays

DEQ Conclusion:

Since disposal of recycled uranium will not be permitted, this interrogatory is closed.

170) Interrogatory CR R313-25-7-170/2: DU Waste Form Release Mechanisms and Rates

DEQ Conclusion:

Closed. As discussed in the DU PA SER (Section 4.1.4), leaching from the waste and potential mobility have been adequately addressed.

171) Interrogatory CR R313-25-7-171/2: Adequacy of DU Cell Buffer Zone

DEQ Conclusion:

The requested reference has been added to Revision 2 of the Energy*Solutions LLRW Disposal License – Condition 35(RML UT2300249) Compliance Report* (ES 2014). Therefore, this interrogatory is closed.

172) Interrogatory CR R313-25-20-172/3: Inadvertent Intruder Protection

DEQ Conclusion:

Closed. See Interrogatory CR R313-25-8(4)(b)-07/2: Applicability of NRC Human Intrusion Scenarios.

173) Interrogatory CR R313-25-7(2)-173/2: Stability of Embankment

DEQ Conclusion:

Energy*Solutions* provided a revised calculation of the loading on the clay liner from large objects indicating that the limit of 3,000 pounds per square foot specified in the *LLRW and 11e.(2) CQA/QC Manual* (ES 2012) was met for two configurations of DU cylinders. Therefore, this interrogatory is closed.

174) Interrogatory CR R313-25-7(6)-174/1: Waste Emplacement in Class A South Disposal Cell

DEQ Conclusion:

Closed, based on responses to Round 1 interrogatories.

175) Interrogatory CR R313-25-7(2)-175/1: Infiltration Rates for the Federal Cell Versus the Class A West Cell

DEQ Conclusion:

As DEQ noted in the Round 3 Interrogatories:

> *ES notes that this interrogatory is no longer relevant since the Federal Cell will use an ET cover. We agree with this position. However, a thorough discussion of the modeling of infiltration rates, with soil hydraulic conductivity values as provided in NUREG/CR-7028 (Benson et al., 2011), is expected in the report on the ET cover system.*

The role of hydraulic conductivity on infiltration rates is extensively discussed in the DU PA SER. See Section 4.1.1.1 and Appendix B. As specifically noted in Section 4.1.1.1:

> *There are still a number of unresolved issues with respect to the selection of parameter ranges, distributions, and correlations, as well as the modeling approach and predicted sensitivities. These concerns are detailed in Appendix B. Further, because the model-predicted infiltration rates may be sensitive to the hydraulic properties assigned to each ET layer, the α and K_{sat} values assumed for modeling moisture in each soil layer within the cover system must be correlated based on experimental data. Also, additional justification is required for the soil property values used in the model by EnergySolutions. Therefore, DEQ does not consider this portion of the performance assessment resolved.*

Therefore, this interrogatory remains open.

176) Interrogatory CR R313-25-8(5)(a)-176/1: Representative Hydraulic Conductivity Rates

DEQ Conclusion:

At this time, DEQ does not accept the Energy*Solutions* position that infiltration results are insensitive to radon barrier changes. As discussed under Interrogatory CR R313-25-7(2)-05/2: Radon Barrier, an appropriate modeling analysis must be performed with DEQ agreement as to values of in-service hydraulic conductivity and correlation between K_{sat} and α (see Appendix E to the DU PA SER). Until that study is performed and the results analyzed, this interrogatory remains open. (See also Appendix B to the DU PA SER.)

177) Interrogatory CR R313-25-8(5)(a)-177/2: Dose from Plant Uptake

DEQ Conclusion:

Interrogatory 177 asks Energy*Solutions* to "*Include a quantitative analysis of dose resulting from plant uptake through 'other wastes' in addition to DU*." As per the DU PA SER, Section 6.2.4, Condition 4:

> *Energy*Solutions *shall submit a revised performance assessment that meets the requirements of that provision and addresses the total quantities of concentrated DU and other radioactive wastes the facility now proposes to dispose in the Federal Cell. This revised performance assessment shall be subject to notice and comment and must be approved by the Director prior to the land disposal of other radioactive waste.*

Thus, for the current Clive DU PA this interrogatory is closed, but it would be reopened if Energy*Solutions* prepared a performance assessment for the disposal of "other wastes" in the proposed Federal Cell.

178) Interrogatory CR R313-25-8(5)(a)-178/2: Surface Water Pathway

DEQ Conclusion:

The Energy*Solutions* position continues to be that, due to the salinity of the groundwater under Clive, the ingestion of groundwater is not a valid exposure pathway and does not need to be evaluated. As stated in the DU PA SER, Section 4.2, DEQ does not agree with the Energy*Solutions* position.

In order to resolve this interrogatory, DEQ has performed its own groundwater ingestion analysis for both the general population (DU PA SER, Section 4.2.2) and the inadvertent intruder (DU PA SER, Section 4.3). The DEQ-calculated groundwater ingestion dose to the general population is well below the UAC R313-25-20 specified limit of 4 mrem/yr for the groundwater pathway. Likewise, the inadvertent intruder calculated groundwater ingestion dose is well below the 500 mrem/yr intruder limit.

No further response from Energy*Solutions* to this interrogatory is required (i.e., this interrogatory is closed). However, Energy*Solutions* may provide additional material meant to justify its position, if it so chooses. Any additional material provided by Energy*Solutions* will be evaluated and, if it is convincing, the appropriate adjustments will be made to SER Sections 4.2 and 4.3.

179) Interrogatory CR R313-25-7(2)-179/1: Rip Rap

DEQ Conclusion:

Energy*Solutions* notes that this interrogatory is no longer relevant for the top slope of the proposed Federal Cell since the Federal Cell will largely use an ET cover. In addition, as noted in Figure 6 of Appendix 2 to the DU PA Model v1.2 (Neptune 2014c), the surface layer on the side slopes contains 50 percent by volume of gravel. Gravel specifications, gradation, construction, and testing requirements are provided in the *LLRW and 11e.(2) CQA/QC Manual* (ES 2012). Based on this information, this interrogatory is closed.

180) Interrogatory CR UGW450005 Part I.D.1-180/2: Compliance Period

DEQ Conclusion:

Section 4.3 of the DU PA SER states:

> *For this DU PA review, DEQ made a simple scoping calculation to show that exclusion of the ingestion pathway would not understate doses in a significant way…. ingestion doses were very small: less than 0.2 mrem/yr. This value is well below the inadvertent intruder dose limit of 500 mrem/yr, as well as the general population dose limit of 4 mrem/yr specified for the groundwater pathway in UAC R313-25-20.*

Therefore, this interrogatory is closed.

181) Interrogatory CR R313-25-19-181/2: Groundwater Mortality

DEQ Conclusion:

While documenting that the groundwater beneath the Clive site is non-potable (and would be lethal if ingested), Energy*Solutions* provided data and a mortality calculation. Interrogatory 181 expressed DEQ's concerns regarding the data and the equation that were utilized by Energy*Solutions* in its calculation. However, DEQ concurs that the groundwater beneath the Clive site is non-potable in its untreated state. Therefore, although the issues raised by Interrogatory 181 have not been adequately addressed, those issues do not have any impact on the outcome of the Clive DU PA, and this interrogatory is closed.

182) Interrogatory CR R313-25-19-182/2: Groundwater Exposure Pathways

DEQ Conclusion:

As discussed in the DU PA SER, inclusion of various scenarios involving the groundwater pathway does not result in significant doses to intruders or the general public. Therefore, this interrogatory is closed.

183) Interrogatory CR R313-25-19-183/2: Meat Ingestion

DEQ Conclusion:

As stated in the Round 2 "Basis for Interrogatory":

> *The information in this interrogatory was transmitted to ES previously, and on May 9, 2014, ES provided updated beef and game ingestion gamma distribution means and standard deviations (EnergySolutions 2014), which are to be incorporated into the DU PA model. The information provided on May 9, 2014, by ES satisfactory addresses this interrogatory, and no additional response is required. This interrogatory is included in order to complete the record of DU PA inquiries.*

Therefore, this interrogatory is closed.

184) Interrogatory CR R313-25-19-184/2: GoldSim Skips Stability Calculations

DEQ Conclusion:

The Clive DU PA Model v1.2 was designed and correctly runs without error within the GoldSim 10.5 (SP4) platform. This interrogatory is closed.

185) Interrogatory CR R313-25-7(10)-185/3: Add Appendix 18 to List of Appendices

DEQ Conclusion:

This interrogatory is simply pointing out a typo. Whether or not the typo has been corrected has no bearing on the Clive DU PA results. Interrogatory 185 is closed.

186) Interrogatory CR R313-25-7(10)-186/3: Sensitivity Analysis Appendix Mis-Referenced

DEQ Conclusion:

This interrogatory is simply pointing out a typo. Whether or not the typo has been corrected has no bearing on the Clive DU PA results. Interrogatory 186 is closed.

187) Interrogatory CR R313-25-19-187/3: Industrial Worker Exposures

DEQ Conclusion:

Closed. See Interrogatory CR R313-25-8(4)(b)-07/2: Applicability of NRC Human Intrusion Scenarios.

188) Interrogatory CR R313-25-7(2)-188/3: Modeling Gullies with SIBERIA

DEQ Conclusion:

In its Round 3 response to this interrogatory, Energy*Solutions* provided the requested model documentation report and a model package containing the EAMS and SIBERIA software, model input files, grids, and results in an attached electronic addendum to Appendix 10, *Erosion Modeling for the Clive DU PA Model* (Neptune 2014g). Since the requested information has been provided, this interrogatory is considered to be closed.

189) Interrogatory CR R313-25-7(2)-189/3: Modeling Impacts of Changes in Federal Cell Cover-System Soil Hydraulic Conductivity and Alpha Values

DEQ Conclusion:

As discussed in the DU PA SER (Section 4.4 and Appendix B), the potential correlation between α and K_{sat} and the changes in K_{sat} with time still need to be resolved. Therefore, this interrogatory remains open.

190) Interrogatory CR R313-25-7(2)-190/3: Likelihood of Seismic Activity

DEQ Conclusion:

Closed, based on responses to Round 3 interrogatories and review of revised text.

191) Interrogatory CR R313-25-7(2)-191/3: Effect of Gully Erosion

DEQ Conclusion:

Interrogatory 191 requested Energy*Solutions* to provide additional information about the ability of steep side slopes to resist gully erosion. In its responses to Round 3 interrogatories, Energy*Solutions* stated that a detailed response concerning the ability of the side slopes to resist gully formation was the available in Appendix K to ES 2013a and Appendix D to ES 2013b. After reviewing both documents [i.e., the Hansen, Allen & Luce (HAL) analyses in Appendix K and Appendix D], DEQ believes that the key analysis is Appendix D to ES 2013b. Appendix D uses both RUSLE and REHM to calculate rill or sheet erosion, with similar results (0.026 mm/yr with RUSLE and 0.016 mm/yr with REHM). Both are well below the EPA's criteria for Resource Conservation and Recovery Act/Comprehensive Environmental Response, Compensation, and Liability Act (RCRA/CERCLA) cover systems. The problem with the Appendix D analysis is that it does not describe how the values for the various RUSLE and REHM parameters were selected. For example, the RUSLE has R, K, L, S, and C parameters, but only L and S are functions of the embankment's design, so the basis for selecting the other parameters is not clear.

Appendix D states: "*The C factor for the top slopes* [0.2] *is based on the sparse vegetative cover naturally found in the areas immediately surrounding the Clive facility*." and "*The C factor for* *the side slope* [0.02] *is based on the higher percentage of gravel in the Unit 4 gravel admixture (50% gravel). The 50% gravel admixture on the side slopes results in a pseudo-gravel mulch once some of the fines have been removed*." There is little detail here to allow anyone to form an opinion as to the acceptability of these values.

The Natural Resources Conservation Service's *National Agronomy Manual* (2002) states:

> *If the surface soil contains a high percentage of gravel or other non-erodible particles that are resistant to abrasion, the surface will become increasingly armored as the erodible particles are carried away. Desert pavement is the classic example of surface armoring. A surface with only non-erodible aggregates exposed to the wind will not erode further except as the aggregates are abraded.*

The Georgia Soil and Water Conservation Commission's *Erosion and Sedimentation Control Manual* (2000), Appendix B-2, Table B-2.5 gives a C value for crushed stone (240 ton/acre) on a 20-degree slope of 0.02. Based on these two sources, the side slope C value may be acceptable, but this type of justification needs to be documented in Appendix D.

Likewise, the Georgia manual indicates that a C factor of 0.2 is representative of land with 20 percent ground cover.

In conclusion, the analysis performed by HAL may or may not be correct, but before DEQ can accept it, each value selected and used in the analysis needs to be justified. Energy*Solutions*/HAL also needs to address how the embankment will be re-vegetated, how much re-vegetation is necessary and how much is expected, and how long is it expected to take. Therefore, this interrogatory remains open.

192) Interrogatory CR R313-25-7(2)-192/3: Implications of Great Salt Lake Freezing on Federal Cell Performance

DEQ Conclusion:

As discussed in the DU PA SER (Section 4.4.4), calculations need to be performed to estimate potential frost depths. Therefore, this interrogatory remains open.

193) Interrogatory CR R313-25-7(2)-193/3: Predominance of Upward or Downward Vertical Flow Direction

DEQ Conclusion:

The DU PA SER (Section 6.2.7), Condition 7 states that:

> *The Licensee shall develop and implement a program to provide more detailed hydrogeologic knowledge of the shallow unconfined aquifer and deeper confined aquifer…. Specific types of information include: groundwater flow velocities, aquifer transmissivities, water quality, sorption properties, and the degree of hydraulic interconnection between the upper and lower aquifers.*

This will be a requirement of any license amendment regarding the disposal of DU waste. Based on the proposed license condition, this interrogatory is closed.

194) Interrogatory CR R313-25-7(2)-194/3: Potential for Development in the Vicinity and at the Site

DEQ Conclusion:

Closed. See Interrogatory CR R313-25-8(4)(b)-07/2: Applicability of NRC Human Intrusion Scenarios.

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U.S. Nuclear Regulatory Commission (NRC), 2014b. "Staff Requirements – SECY-13-0075 – Proposed Rule: Low-Level Radioactive Waste Disposal (10 CFR Part 61) (RIN 3150-A192)," SRM-SECY-13-0075, February 12.

U.S. Nuclear Regulatory Commission (NRC), 2014c. "Status Update on the 10 CFR Part 61 Low-Level Radioactive Waste Disposal Rulemaking: Commission SRMs and Staff's Activities," U.S. Nuclear Regulatory Commission, Andrew Carrera, Office of Federal and State Materials and Environmental Management Programs, presented at Fuel Cycle Information Exchange 2014, June 11.

Appendix D – LIMITATIONS ON TRANSURANICS

OFFICE OF THE ATTORNEY GENERAL, STATE OF UTAH MEMORANDUM

TO: Helge Gabert, Project Manager
Energy*Solutions* Depleted Uranium Performance Assessment

FROM: Laura Lockhart, Assistant Attorney General
Utah Attorney General's Office

DATE: April 6, 2015

RE: Applicability of transuranic limitations in the Northwest Interstate Compact on Low-level Radioactive Waste Management

The founding document for the Northwest Interstate Compact on Low-level Radioactive Waste Management ("Compact") contains language limiting disposal of waste contaminated with transuranics, as described below. This memo is in response to your request for advice about how that Compact language affects what may be disposed of at Energy*Solutions*. Unfortunately, as described below, a resolution of this interpretation requires that the State of Utah engage with the Compact since it is their law that must be interpreted.

This memo includes my legal advice to you, but is not a formal Attorney General opinion and does not reflect any determination made by the Attorney General.

Compact Language

The definition of low-level waste for purposes of the Compact includes the following restriction:

> "Low-level waste" does not include waste containing more than ten (10) nanocuries of transuranic contaminants per gram of material, nor spent reactor fuel, nor material classified as either high-level waste or waste which is unsuited for disposal by near-surface burial under any applicable federal regulations.

Title II, Omnibus Low-Level Radioactive Waste Interstate Compact Consent Act, Pub. L. No. 99-240, § 221, 99 Stat. 1861 (1986) (42 U.S.C. §2021d note) (emphasis added).[1] The Compact is also adopted by each Compact member. See Utah Code Ann. Title 19, Chapter 3, Part 2, and particularly

[1] This law is also called the Low-level Radioactive Waste Policy Amendments Act of 1985. Note that this prohibition is somewhat similar to a Class A limit of 10 nanocuries/gram of "alpha emitting transuranic radionuclides with half-life greater than five years," found in DRC waste classification rules (see Utah Admin. Code R313-15-1009, Table 1 and paragraph (d)(i)). However, it is more expansive because it also includes beta-emitting radionuclides and materials with half-lives of less than five years.

Memorandum to Helge Gabert
April 6, 2015
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Utah Code Ann. § 19-3-201.1(4)(b). The implication of this language is that waste containing more than 10 nanocuries transuranic contaminants per gram of material is considered to be more than low-level radioactive waste, for Compact purposes.

Compact's Third Amended Resolution and Order

The Compact's "Third Amended Resolution and Order," dated May 1, 2006, is the mechanism the Compact has used to allow disposal of low-level radioactive waste at Energy*Solutions*. This language, which includes a definition, is found in that document:

> Low-level radioactive waste (as defined in Public Law 99-240) as allowed under, and regulated by the terms of, the radioactive materials license of Energy*Solutions* as determined by the State of Utah, is allowed access to the Energy*Solutions* facility in the Northwest Interstate Compact region.

Compact's "Third Amended Resolution and Order," dated May 1, 2006, ¶ 2. The approval also includes this language:

> It is the intent of the Committee that only those wastes approved by the compact of origin (including the Northwest Compact) be allowed . . . .
> Id., at ¶ 5.

Definitional Language in the Low-Level Radioactive Waste Policy Amendments Act (Public Law 99-240)

The Low-level Radioactive Waste Policy Amendments Act (Public Law 99-240) ("Act") includes the following definition:

> Low-level Radioactive Waste.—The term 'low-level radioactive waste' means radioactive material that—
> "(A) is not high-level radioactive waste, spent nuclear fuel, or byproduct material (as defined in section lle.(2) of the Atomic Energy Act of 1954 (42 U.S.C. 2014(e)(2))); and
> "(B) the Nuclear Regulatory Commission, consistent with existing law and in accordance with paragraph (A), classifies as low-level radioactive waste.

[2] *See* http://www.ecy.wa.gov/nwic/resolution_3.pdf (paste this link into a browser's address bar if necessary). The Compact's authority over disposal at Energy*Solutions* was confirmed by the 10[th] Circuit in *EnergySolutions, L.L.C. v. Utah*, 625 F.3d 1261 (10th Cir. 2010).

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Title I, Low-level Radioactive Waste Policy Amendments Act of 1985, Pub. L. No. 99-240, Section 102 Section 2(9), 99 Stat. 1843) (1986) (codified as 42 U.S.C. §2021b(9)). By this definition, low-level waste includes the transuranic contaminants that are not included in the Compact definition.

As discussed above, the Act also included the text of the Northwest Interstate Compact on Low-level Radioactive Waste Management. See 42 U.S.C. § 2021d, note.

Analysis

Energy*Solutions* has been authorized to dispose of low-level radioactive waste by the Compact, but the interpretation of that term is unclear. The term "as defined by Public Law 99-240" could be read to be a reference to the definition codified at 42 U.S.C. § 2021b(9). Alternatively, it could refer to the separate, Compact-only definition in the Compact that is also part of the legislation in Section 221, as described above. The former interpretation has some intuitive appeal. The latter may be more consistent with the Compact's own authority, however. It is unclear to me how, after Congress has carved away the Compact's authority over disposal of waste with transuranic contaminants by adopting the Compact's definition, the Compact can then authorize disposal of that waste within Compact disposal facilities.

This is a complex question regarding Compact authority that requires the participation of the Compact to resolve. I informally initiated contact with Compact authorities, but it is clear that more formal discussions will be required. If your goal is to be certain that the State of Utah is complying with Compact requirements, the only way to do that before the question is resolved is to impose restrictions that meet the Compact requirement to prohibit the disposal of "waste containing more than 10 nanocuries of transuranic contaminants per gram of material."

For wastes generated within the Northwest Interstate Compact and within the Rocky Mountain Compact, the question is a little simpler. Because both of those Compacts prohibit disposal of waste containing more than 10 nanocuries of transuranic contaminants per gram, and because Northwest Interstate Compact facilities are not permitted to take waste that cannot be disposed of in the compact of origin, transuranic-contaminated waste from those compacts would be prohibited.

Appendix E – HYDRAULIC PROPERTIES FOR SIMULATING THE HYDROLOGY OF THE WATER BALANCE COVER AT THE ENERGY*SOLUTIONS* SITE IN CLIVE, UTAH

CRAIG H. BENSON, PHD, PE, NAE

MEMORANDUM

To: David Back

From: Craig H. Benson

Date: 1 March 2015

Re: Hydraulic properties for simulating the hydrology of the water balance cover at the Energy Solutions site in Clive, UT

Attachment: Excel worksheet "Hyd Props Calculator.xls"

This memorandum describes a method to create statistically valid and realistic stochastic realizations of correlated hydraulic properties for use in variably saturated flow simulations for water balance covers. The method relies on recommendations for hydraulic properties in NUREG CR-7028 (Benson et al. 2011) and statistical data reported in Benson and Gurdal (2013).

NUREG Recommendations

The hydraulic properties in Table 1 are recommended in NUREG CR-7028 for variably saturated flow simulations of water balance covers for LLW disposal facilities. These properties include the saturated hydraulic conductivity (K_s), the van Genuchten parameters α and n describing the soil water characteristic curve (SWCC), the saturated water content (θ_s), and the residual water content (θ_r). The properties in Table 1 are representative of longer-term conditions and account for the impacts of pedogenesis on soil structure and hydraulic behavior.

These properties can be used to simulate the radon barrier, frost protection layer, and the evaporative zone layer in the water balance cover proposed for the LLW disposal facility operated by Energy Solutions in Clive, Utah. These properties can also be used to simulate the surface layer after adjusting the saturated water content for elevated gravel content, as described in Bareither and Benson (2013).

Accounting for Uncertainty

Uncertainty arising from spatial variability in hydraulic properties can be evaluated by conducting simulations using parameters representative of the properties in Table 1 that also account for representative spatial variations observed in the field. Spatial variations are normally accounted for by treating the hydraulic properties as spatial random variables described using statistical distributions.

Based on an analysis of data from 37 different as-built cover soils from the Alternative Cover Assessment Program (ACAP), Benson and Gurdal (2013) concluded that the spatial variability of K_s and α can be described by the lognormal distribution, whereas a normal distribution can be used to describe spatial variability of n and θ_s. Benson and Gurdal (2013) also indicate that K_s and α exhibit cross-correlation, with a correlation

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coefficient of 0.48 describing the correlation between lnK_S and lnα. Standard deviations for each of the 37 cover soils are also reported in Benson and Gurdal (2013).

The soils evaluated in Benson and Gurdal (2013) represent as-built conditions rather than long-term conditions. Pedogenesis occurring post-construction is known to alter hydraulic properties. These alterations generally cause systematic changes in the properties (e.g., an overall increase in K_s or α, Benson et al. 2007, 2011). In contrast, the spatial variability present in the as-built condition is likely to persist even as the soils change due to weathering and other pedogenic processes. Thus, the statistical properties reported by Benson and Gurdal (2013) that describe spatial variability of as- built covers can be used as surrogates for statistical properties describing spatial variability in longer-term conditions.

The standard deviations reported in Tables 1 and 2 of Benson and Gurdal (2013) were analyzed to determine representative standard deviations for use in variability saturated flow modeling of water balance covers. Box plots for the standard deviations are shown in Fig. 1 and order statistics for the standard deviations are shown in Fig. 2. These data sets were used to define low, typical, and high levels of spatial variability for lnK_s, lnα, n, and θ_S corresponding to the 20th percentile order statistic (low), 50th percentile order statistic (or median, for typical), and 80th percentile order statistic (high) for each variable. Standard deviations corresponding to these conditions are summarized in Table 2.

Monte Carlo Simulator

A spreadsheet was created to compute random realizations of lnK_s, lnα, n, and θ_S that can be used as input to a variably saturated flow model. The spreadsheet uses a multivariate normal distribution (MVN) with cross-correlation to describe the spatial variation of each variable as well as the cross-correlation between lnK_s and lnα. Cholesky decomposition is used to solve the linear system of equations corresponding to each set of realizations.

The input and output from the spreadsheet is shown in Fig. 3. Means and standard deviations are entered in the boxes with yellow highlighting in the “Input” area. Cross-correlation coefficients are entered in the cells with yellow highlighting in the “Correlation Coefficients” section. Practical upper and lower bounds for each of the parameters are in the yellow highlighted cells in the “Controls” section.

The randomly generated realizations are shown in the orange highlighted cells in the “Outputs” section. Each row represents one set of random realizations. The column “Control Check” indicates if any of the realizations in a row exceeds the bounds stipulated in the “Controls” section. Rows with the Control Check indicating FALSE (e.g., Rows 6 and 7 in Fig. 3) are discarded and additional rows are added at the bottom of the sheet to generate new sets of parameters to replace those not meeting the ranges in the “Controls” section.

Examples are shown in Figs. 4-7 of 100 realizations created with the spreadsheet using the typical parameters in Table 1 as means, the typical standard deviations in Table 2, and a correlation coefficient of 0.48 describing the cross-correlation between lnK_s and lnα described in Benson and Gurdal (2013).

References

Bareither, C. and Benson, C. (2013), Evaluation of Bouwer-Rice Large-Particle Correction Procedure For Soil Water Characteristic Curves, *Geotechnical Testing J.*, 36(5), 680-694.

Benson, C. and Gurdal, T. (2013), Hydrologic Properties of Final Cover Soils, Foundation Engineering in the Face of Uncertainty, *GSP No. 229*, J. Withiam et al., Eds., ASCE, Reston VA, 283-297.

Benson, C., Albright, W., Fratta, D., Tinjum, J., Kucukkirca, E., Lee, S., Scalia, J., Schlicht, P., Wang, X. (2011), Engineered Covers for Waste Containment: Changes in Engineering Properties & Implications for Long-Term Performance Assessment, NUREG/CR-7028, Office of Research, U.S. Nuclear Regulatory Commission, Washington.

Table 1. Hydraulic properties recommended for fine-textured cover soils in NUREG CR-7028.

Parameter	Units	Range	Typical
K_s	m/s	$1x10^{-7}$ to $5x10^{-6}$	$5x10^{-7}$
α	1/kPa	0.01 to 0.33	0.2
n	-	1.2 to 1.4	1.3
θ_s	-	0.35 to 0.45	0.4
θ_r	-	0.0	0.0

Table 2. Recommended standard deviations for $\ln K_s$, $\ln\alpha$, n, and θ_s based on analysis of data in Benson and Gurdal (2013).

Parameter	Base Units	Low	Typical	High
$\ln K_s$	m/s	0.59	1.15	2.37
$\ln\alpha$	1/kPa	0.12	0.55	1.04
n	-	0.04	0.10	0.27
θ_s	-	0.013	0.020	0.030

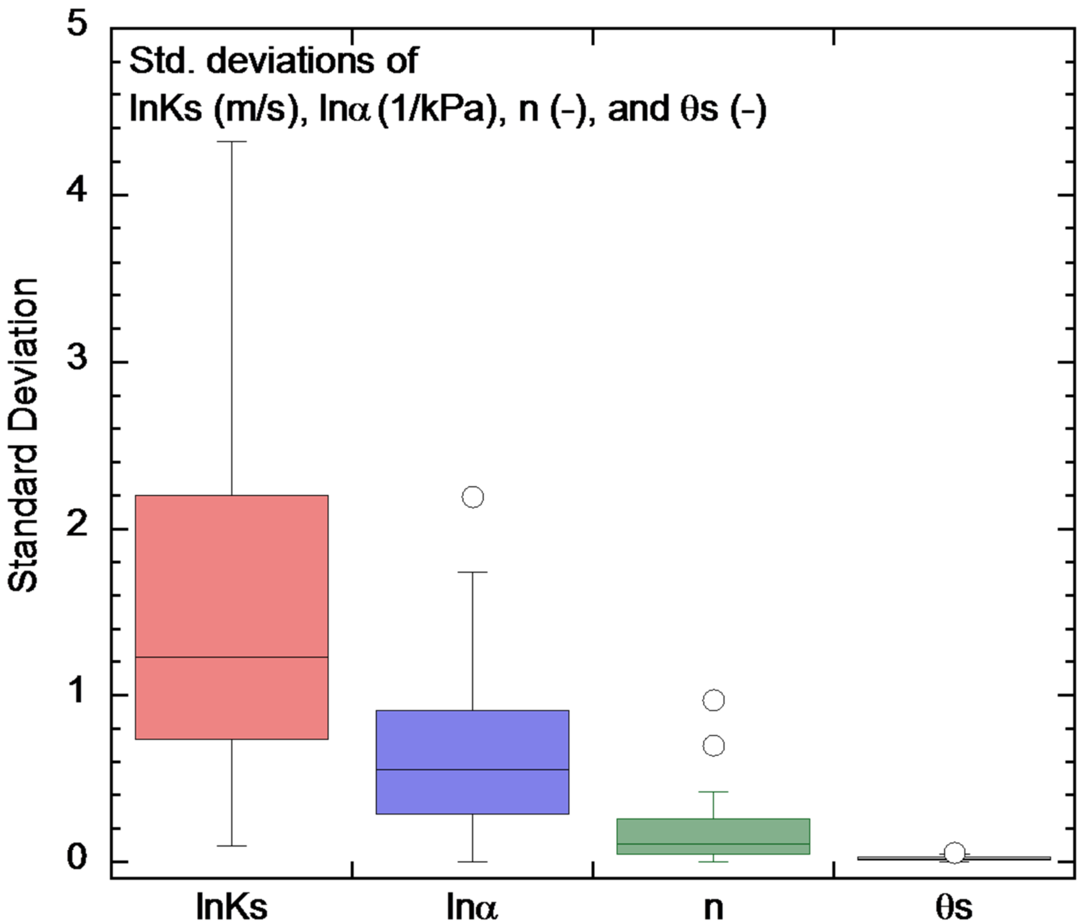


Fig. 1. Box plots of standard deviations for K_s, α, n, and θ_s for data reported in Benson and Gurdal (2013).

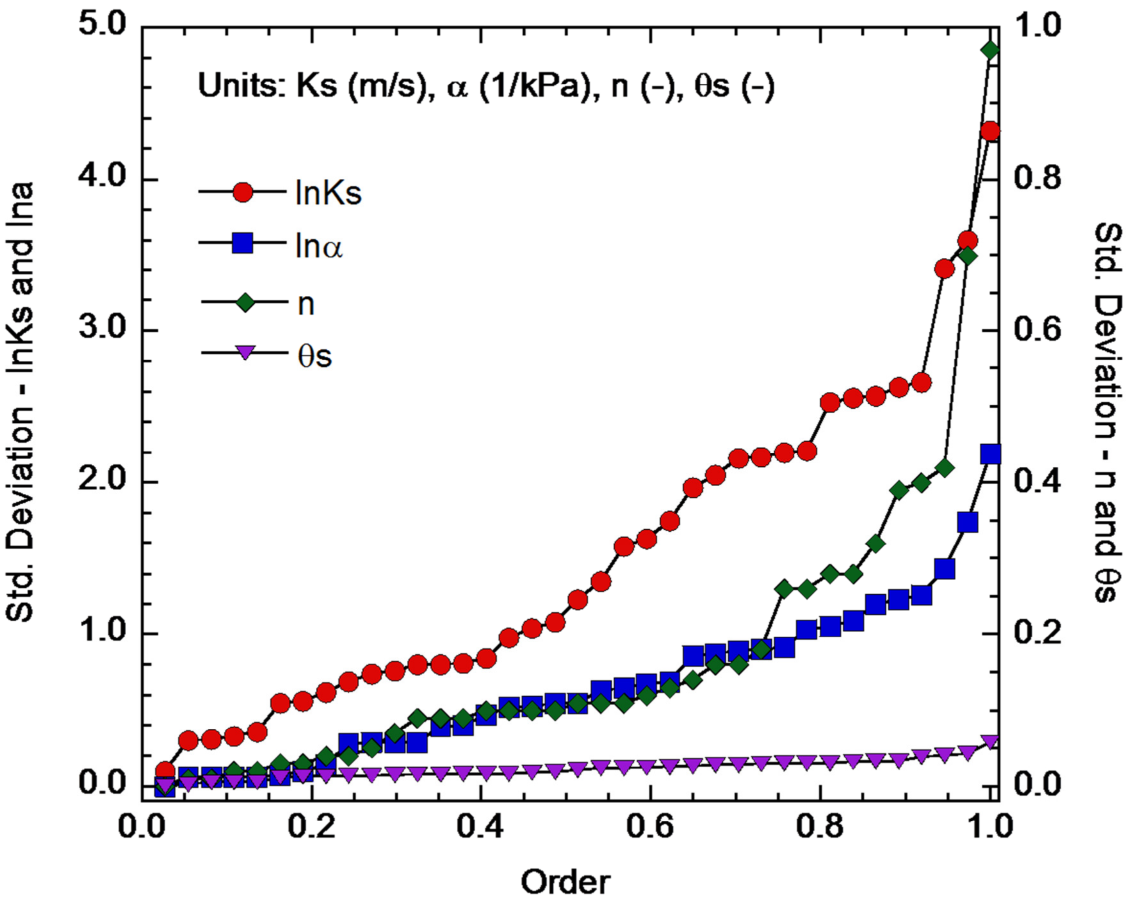
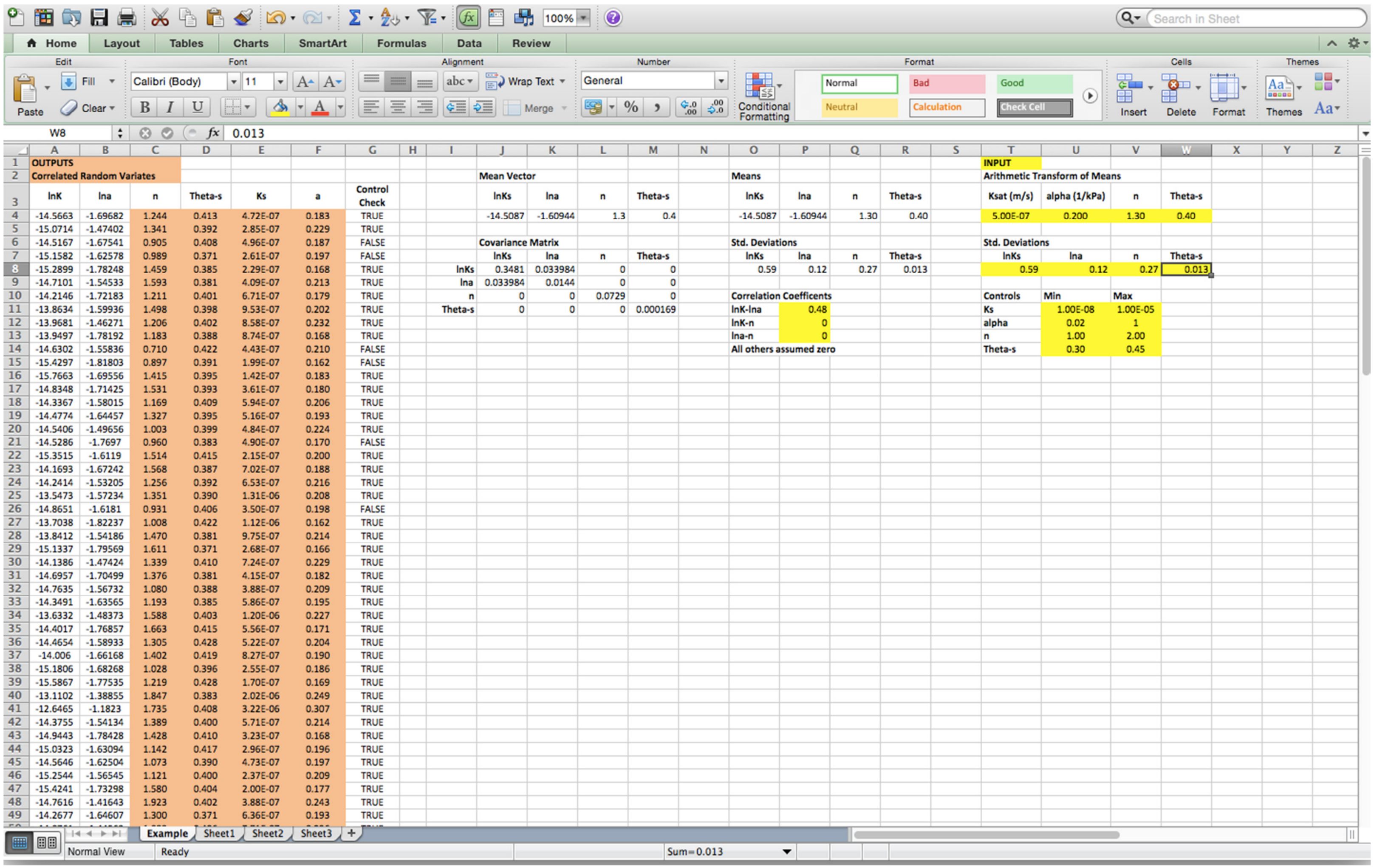


Fig. 2. Order statistics of standard deviations for K_s, α, n, and θ_s for data reported in Benson and Gurdal (2013).



OUTPUTS
Correlated Random Variates

	lnK	lna	n	Theta-s	Ks	a	Control Check
4	-14.5663	-1.69682	1.244	0.413	4.72E-07	0.183	TRUE
5	-15.0714	-1.47402	1.341	0.392	2.85E-07	0.229	TRUE
6	-14.5167	-1.67541	0.905	0.408	4.96E-07	0.187	FALSE
7	-15.1582	-1.62578	0.989	0.371	2.61E-07	0.197	FALSE
8	-15.2899	-1.78248	1.459	0.385	2.29E-07	0.168	TRUE
9	-14.7101	-1.54533	1.593	0.381	4.09E-07	0.213	TRUE
10	-14.2146	-1.72183	1.211	0.401	6.71E-07	0.179	TRUE
11	-13.8634	-1.59936	1.498	0.398	9.53E-07	0.202	TRUE
12	-13.9681	-1.46271	1.206	0.402	8.58E-07	0.232	TRUE
13	-13.9497	-1.78192	1.183	0.388	8.74E-07	0.168	TRUE
14	-14.6302	-1.55836	0.710	0.422	4.43E-07	0.210	FALSE
15	-15.4297	-1.81803	0.897	0.391	1.99E-07	0.162	FALSE
16	-15.7663	-1.69556	1.415	0.395	1.42E-07	0.183	TRUE
17	-14.8348	-1.71425	1.531	0.393	3.61E-07	0.180	TRUE
18	-14.3367	-1.58015	1.169	0.409	5.94E-07	0.206	TRUE
19	-14.4774	-1.64457	1.327	0.395	5.16E-07	0.193	TRUE
20	-14.5406	-1.49656	1.003	0.399	4.84E-07	0.224	TRUE
21	-14.5286	-1.7697	0.960	0.383	4.90E-07	0.170	FALSE
22	-15.3515	-1.6119	1.514	0.415	2.15E-07	0.200	TRUE
23	-14.1693	-1.67242	1.568	0.387	7.02E-07	0.188	TRUE
24	-14.2414	-1.53205	1.256	0.392	6.53E-07	0.216	TRUE
25	-13.5473	-1.57234	1.351	0.390	1.31E-06	0.208	TRUE
26	-14.8651	-1.6181	0.931	0.406	3.50E-07	0.198	FALSE
27	-13.7038	-1.82237	1.008	0.422	1.12E-06	0.162	TRUE
28	-13.8412	-1.54186	1.470	0.381	9.75E-07	0.214	TRUE
29	-15.1337	-1.79569	1.611	0.371	2.68E-07	0.166	TRUE
30	-14.1386	-1.47424	1.339	0.410	7.24E-07	0.229	TRUE
31	-14.6957	-1.70499	1.376	0.381	4.15E-07	0.182	TRUE
32	-14.7635	-1.56732	1.080	0.388	3.88E-07	0.209	TRUE
33	-14.3491	-1.63565	1.193	0.385	5.86E-07	0.195	TRUE
34	-13.6332	-1.48373	1.588	0.403	1.20E-06	0.227	TRUE
35	-14.4017	-1.76857	1.663	0.415	5.56E-07	0.171	TRUE
36	-14.4654	-1.58933	1.305	0.428	5.22E-07	0.204	TRUE
37	-14.006	-1.66168	1.402	0.419	8.27E-07	0.190	TRUE
38	-15.1806	-1.68268	1.028	0.396	2.55E-07	0.186	TRUE
39	-15.5867	-1.77535	1.219	0.428	1.70E-07	0.169	TRUE
40	-13.1102	-1.38855	1.847	0.383	2.02E-06	0.249	TRUE
41	-12.6465	-1.1823	1.735	0.408	3.22E-06	0.307	TRUE
42	-14.3755	-1.54134	1.389	0.400	5.71E-07	0.214	TRUE
43	-14.9443	-1.78428	1.428	0.410	3.23E-07	0.168	TRUE
44	-15.0323	-1.63094	1.142	0.417	2.96E-07	0.196	TRUE
45	-14.5646	-1.62504	1.073	0.390	4.73E-07	0.197	TRUE
46	-15.2544	-1.56545	1.121	0.400	2.37E-07	0.209	TRUE
47	-15.4241	-1.73298	1.580	0.404	2.00E-07	0.177	TRUE
48	-14.7616	-1.41643	1.923	0.402	3.88E-07	0.243	TRUE
49	-14.2677	-1.64607	1.300	0.371	6.36E-07	0.193	TRUE

Mean Vector

lnKs	lna	n	Theta-s
-14.5087	-1.60944	1.3	0.4

Covariance Matrix

	lnKs	lna	n	Theta-s
lnKs	0.3481	0.033984	0	0
lna	0.033984	0.0144	0	0
n	0	0	0.0729	0
Theta-s	0	0	0	0.000169

Means

lnKs	lna	n	Theta-s
-14.5087	-1.60944	1.30	0.40

Std. Deviations

lnKs	lna	n	Theta-s
0.59	0.12	0.27	0.013

Correlation Coefficents

lnK-lna	0.48
lnK-n	0
lna-n	0
All others assumed zero	

INPUT
Arithmetic Transform of Means

Ksat (m/s)	alpha (1/kPa)	n	Theta-s
5.00E-07	0.200	1.30	0.40

Std. Deviations

lnKs	lna	n	Theta-s
0.59	0.12	0.27	0.013

Controls	Min	Max
Ks	1.00E-08	1.00E-05
alpha	0.02	1
n	1.00	2.00
Theta-s	0.30	0.45

Fig. 3. Hydraulic properties calculator to generate correlated realizations for K_s, α, n, θ_s from a multivariate normal distribution for normally distributed $\ln K_s$, $\ln\alpha$, n, and θ_s with cross-correlations between variates. **Macros must be enabled on launch for the spreadsheet to function properly.**

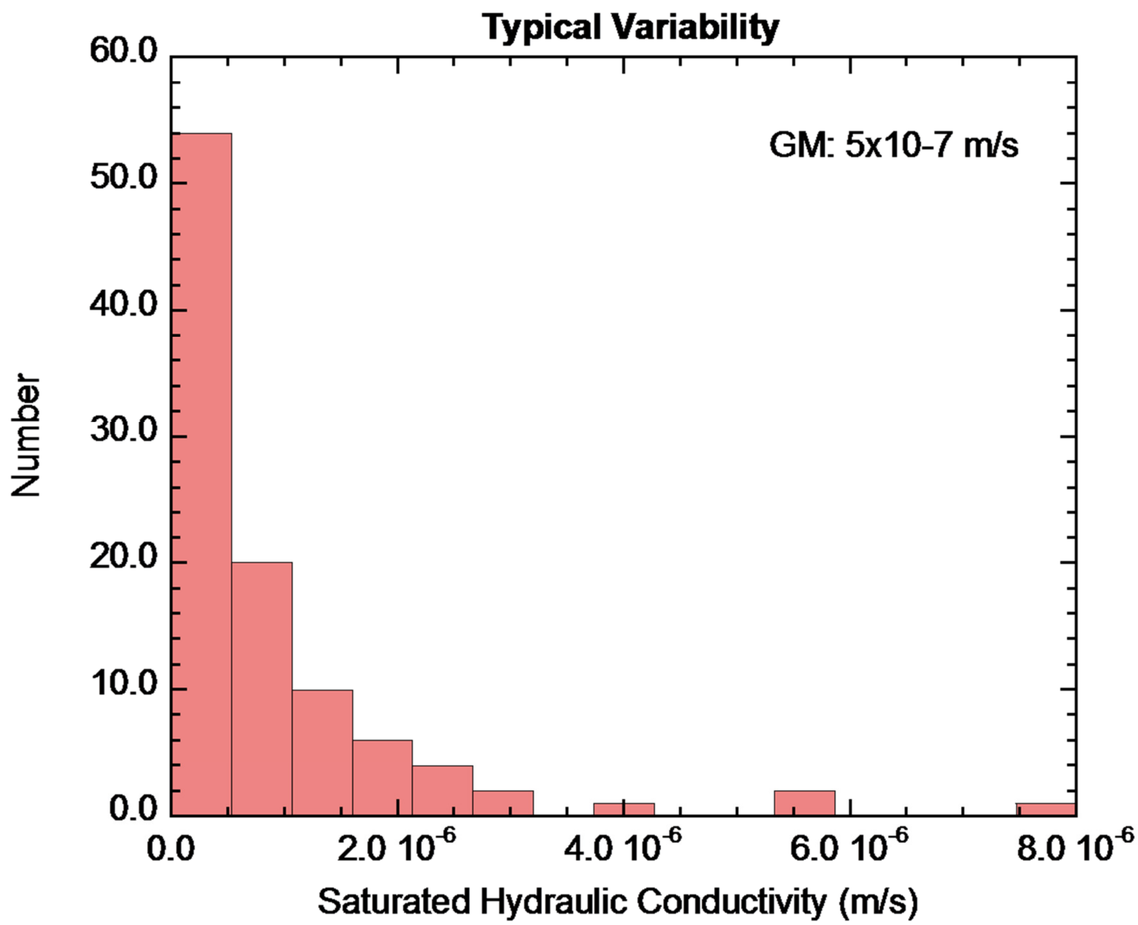


Fig. 4. Histogram of saturated hydraulic conductivity for geometric mean hydraulic conductivity of $5x10^{-7}$ m/s, cross-correlation between $\ln K_s$ and $\ln\alpha$= 0.48, and typical level of spatial variability. Cross-correlation and spatial variability of variates from Benson and Gurdal (2013).

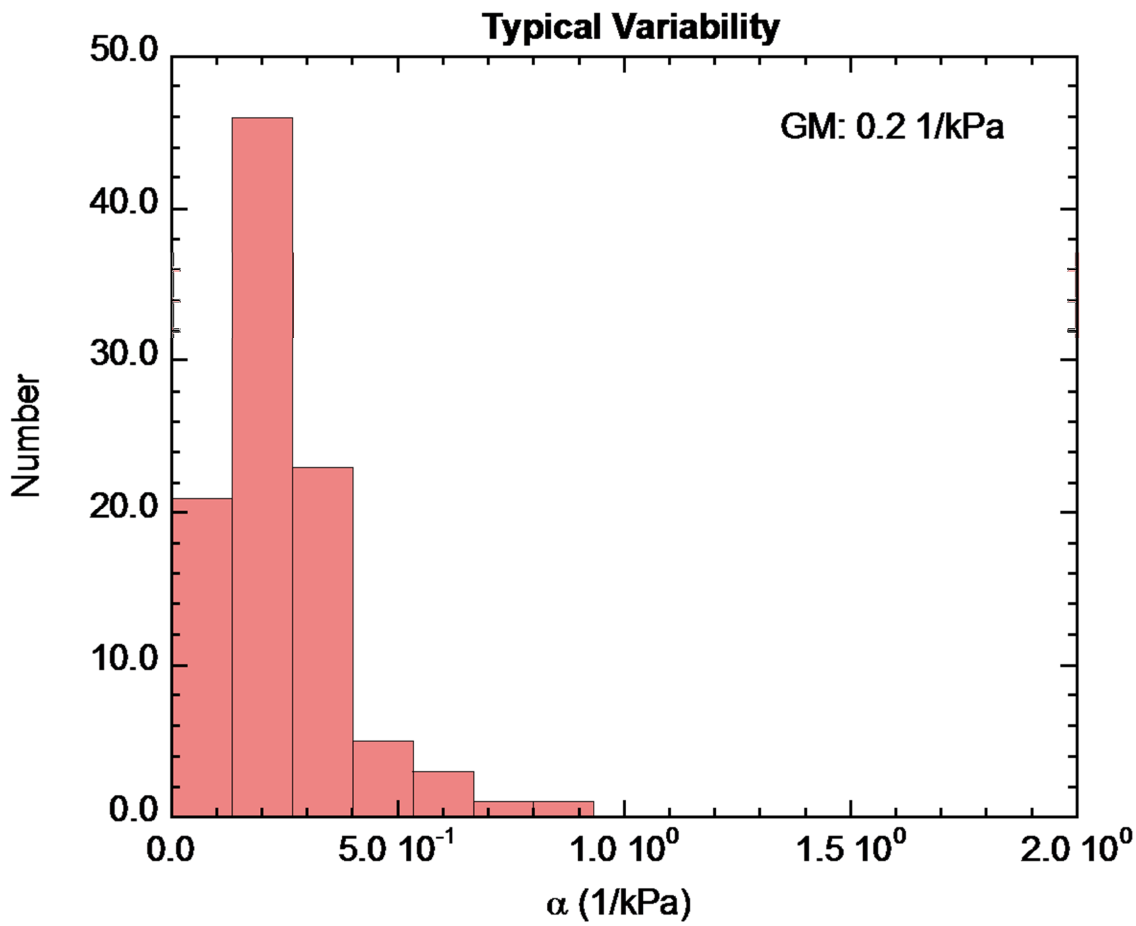


Fig. 5. Histogram of van Genuchten's α parameter for a geometric mean of 0.2 1/kPa, cross-correlation between $\ln K_s$ and $\ln\alpha$ = 0.48, and typical level of spatial variability. Cross-correlation and spatial variability of variates from Benson and Gurdal (2013).

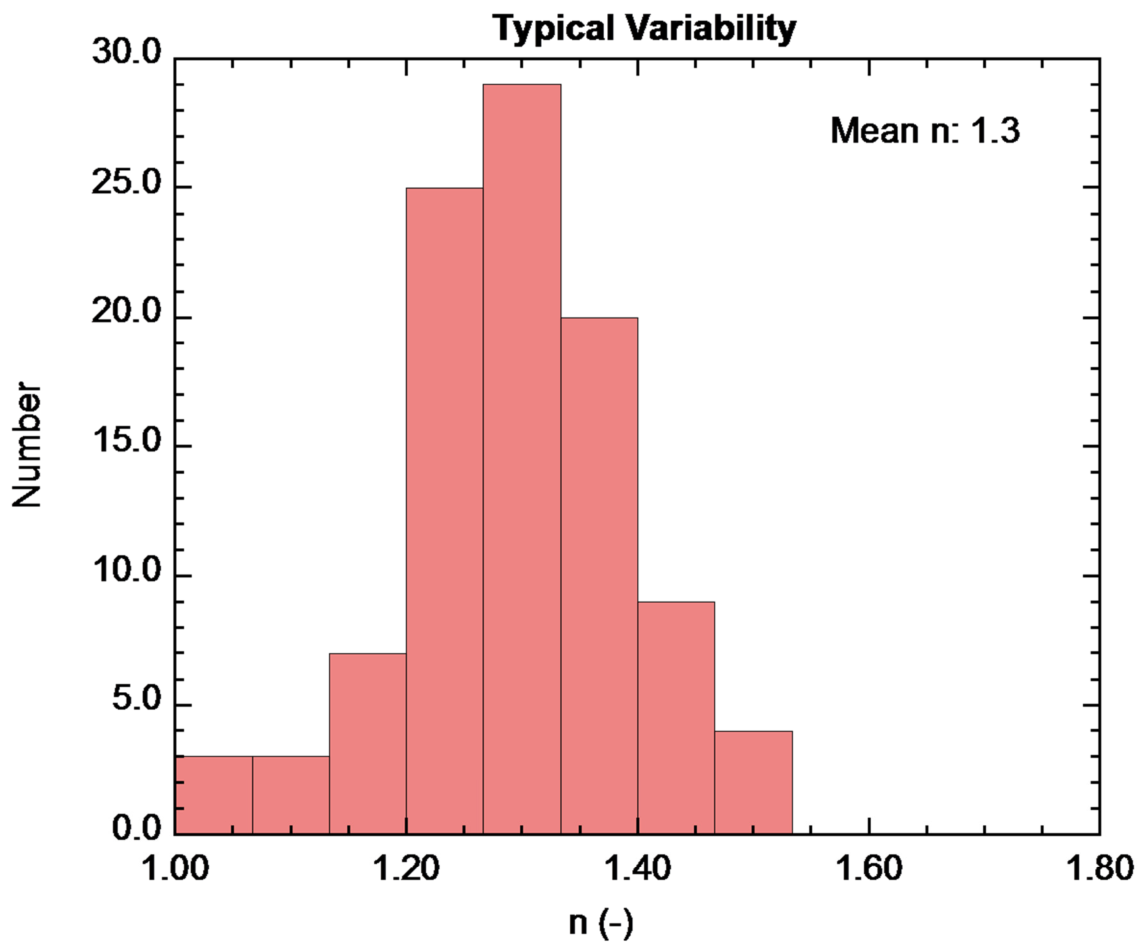


Fig. 6. Histogram of van Genuchten's n parameter for a mean n of 1.3 (unitless), cross-correlation between $\ln K_s$ and $\ln\alpha$ = 0.48, and typical level of spatial variability. Cross-correlation and spatial variability of variates from Benson and Gurdal (2013).

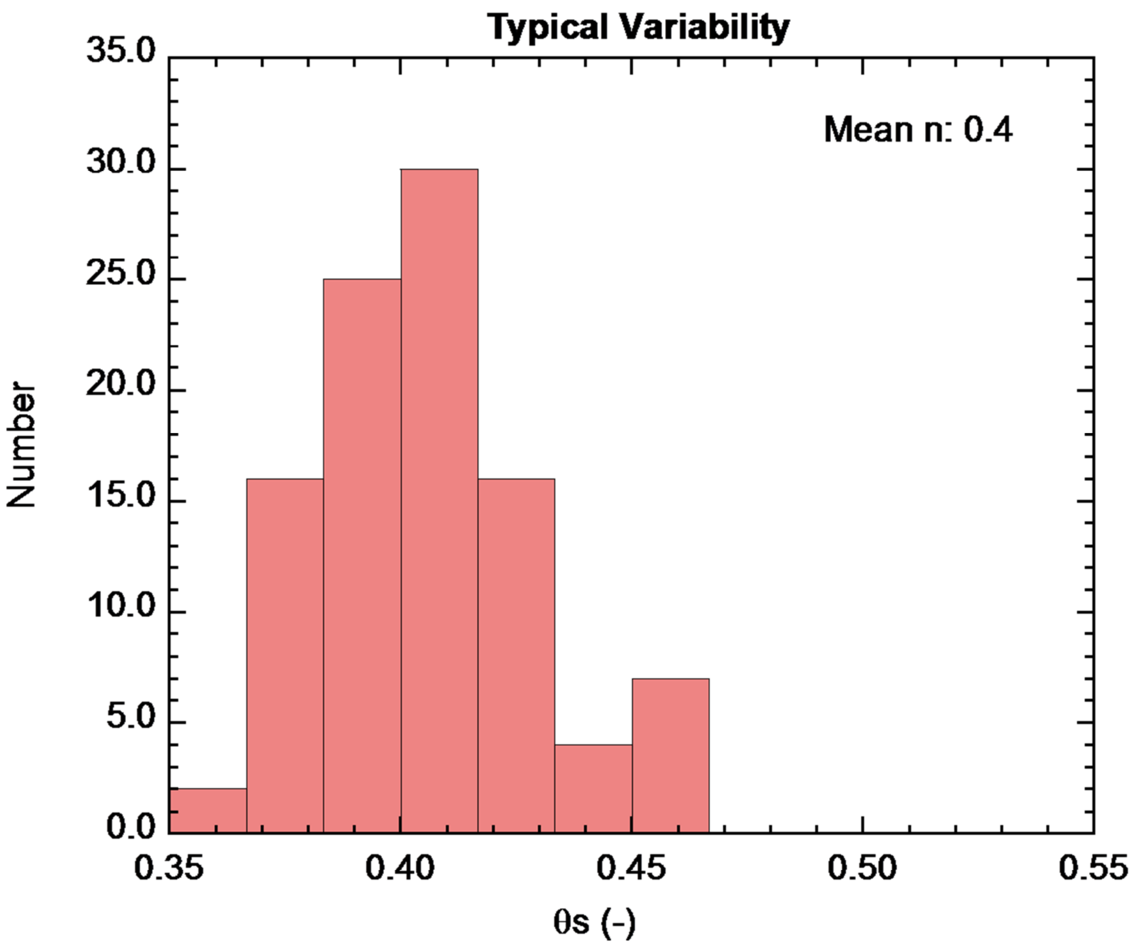


Fig. 7. Histogram of saturated volumetric water content for a mean n of 0.40 (unitless), cross, cross-correlation between $\ln K_s$ and $\ln\alpha$ = 0.48, and typical level of spatial variability. Cross-correlation and spatial variability of variates from Benson and Gurdal (2013).

A Microsoft Word copy of the referenced Excel file, Appendix-H-Hyd Props Calculator.xls, follows beginning on the next page:

OUTPUTS																INPUT		
Correlated Random Variates								Mean Vector				Means				Arithmetic Transform of Means		
lnK	lna	n	Theta-s	Ks	a	Control Check		lnKs	lna	n	Theta-s	lnKs	lna	n	Theta-s	Ksat (m/s)	alpha (1/kPa)	n
-13.5403	-1.57982	1.458	0.402	1.32E-06	0.206	TRUE		-14.5087	-1.60944	1.3	0.4	-14.5087	-1.60944	1.30	0.40	5.00E-07	0.200	1.30
-14.1393	-1.55929	1.748	0.404	7.23E-07	0.210	TRUE												
-15.4318	-1.58753	1.274	0.382	1.99E-07	0.204	TRUE		Covariance Matrix				Std. Deviations				Std. Deviations		
-14.1998	-1.64663	1.311	0.396	6.81E-07	0.193	TRUE		lnKs	lna	n	Theta-s	lnKs	lna	n	Theta-s	lnKs	lna	n
-14.2702	-1.50924	0.972	0.400	6.35E-07	0.221	FALSE	lnKs	0.3481	0.033984	0	0	0.59	0.12	0.27	0.013	0.59	0.12	0.27
-13.6351	-1.55757	1.119	0.398	1.20E-06	0.211	TRUE	lna	0.033984	0.0144	0	0							
-14.8971	-1.59854	1.493	0.416	3.39E-07	0.202	TRUE	n	0	0	0.0729	0	Correlation Coefficients				Controls	Min	Max
-15.0915	-1.66905	1.902	0.400	2.79E-07	0.188	TRUE	Theta-s	0	0	0	0.000169	lnK-lna	0.48			Ks	1.00E-08	1.00E-05
-15.2052	-1.3974	1.357	0.403	2.49E-07	0.247	TRUE						lnK-n	0			alpha	0.02	1
-15.1818	-1.76464	1.335	0.390	2.55E-07	0.171	TRUE						lna-n	0			n	1.00	2.00
-14.17	-1.43703	1.104	0.360	7.02E-07	0.238	TRUE						All others assumed zero				Theta-s	0.30	0.45
-14.7235	-1.68203	1.148	0.393	4.03E-07	0.186	TRUE												
-14.7926	-1.54147	1.622	0.397	3.76E-07	0.214	TRUE												
-14.3762	-1.61608	0.761	0.395	5.71E-07	0.199	FALSE												
-13.7053	-1.46669	1.323	0.411	1.12E-06	0.231	TRUE												
-13.9691	-1.54604	1.489	0.397	8.58E-07	0.213	TRUE												
-14.0589	-1.74194	1.200	0.400	7.84E-07	0.175	TRUE												
-13.3519	-1.62216	1.236	0.412	1.59E-06	0.197	TRUE												
-14.4119	-1.50126	0.936	0.403	5.51E-07	0.223	FALSE												
-14.9927	-1.73426	1.011	0.416	3.08E-07	0.177	TRUE												
-15.0875	-1.59921	1.473	0.361	2.80E-07	0.202	TRUE												
-14.6023	-1.6606	1.615	0.421	4.55E-07	0.190	TRUE												
-14.0893	-1.52848	1.224	0.397	7.61E-07	0.217	TRUE												
-14.6546	-1.79404	1.261	0.406	4.32E-07	0.166	TRUE												

OUTPUTS																**INPUT**		
Correlated Random Variates								**Mean Vector**				**Means**				**Arithmetic Transform of Means**		
lnK	**lna**	**n**	**Theta-s**	**Ks**	**a**	**Control Check**		**lnKs**	**lna**	**n**	**Theta-s**	**lnKs**	**lna**	**n**	**Theta-s**	**Ksat (m/s)**	**alpha (1/kPa)**	**n**
-14.7208	-1.61448	0.824	0.411	4.04E-07	0.199	FALSE												
-14.3078	-1.69148	1.051	0.409	6.11E-07	0.184	TRUE												
-14.9577	-1.53133	1.592	0.401	3.19E-07	0.216	TRUE												
-13.8601	-1.60704	1.669	0.411	9.56E-07	0.200	TRUE												
-13.9653	-1.47232	1.307	0.418	8.61E-07	0.229	TRUE												
-15.2815	-1.71273	1.404	0.414	2.31E-07	0.180	TRUE												
-14.6284	-1.56627	1.032	0.394	4.44E-07	0.209	TRUE												
-15.4236	-1.83153	1.086	0.403	2.00E-07	0.160	TRUE												
-15.749	-1.70114	1.537	0.407	1.45E-07	0.182	TRUE												
-14.8327	-1.72311	1.743	0.405	3.62E-07	0.179	TRUE												
-14.3347	-1.5869	1.273	0.384	5.95E-07	0.205	TRUE												
-14.4755	-1.65188	1.430	0.407	5.17E-07	0.192	TRUE												
-14.5388	-1.50831	1.144	0.412	4.85E-07	0.221	TRUE												
-14.5268	-1.79537	1.118	0.399	4.91E-07	0.166	TRUE												
-15.3465	-1.62034	1.702	0.390	2.16E-07	0.198	TRUE												
-14.1671	-1.68323	1.889	0.401	7.04E-07	0.186	TRUE												
-14.2394	-1.53951	1.356	0.404	6.55E-07	0.214	TRUE												
-14.9451	-1.55118	0.914	0.404	3.23E-07	0.212	FALSE												
-13.8424	-1.62019	0.996	0.418	9.73E-07	0.198	FALSE												
-13.9506	-1.48655	1.463	0.376	8.74E-07	0.226	TRUE												
-15.2596	-1.7233	1.599	0.425	2.36E-07	0.178	TRUE												
-14.6187	-1.5787	1.215	0.398	4.48E-07	0.206	TRUE												
-14.7641	-1.6438	1.369	0.375	3.87E-07	0.193	TRUE												
-14.8355	-1.44227	1.071	0.386	3.61E-07	0.236	TRUE												

OUTPUTS																	**INPUT**		
Correlated Random Variates								**Mean Vector**				**Means**					**Arithmetic Transform of Means**		
lnK	**lna**	**n**	**Theta-s**	**Ks**	**a**	**Control Check**		**lnKs**	**lna**	**n**	**Theta-s**	**lnKs**	**lna**	**n**	**Theta-s**		**Ksat (m/s)**	**alpha (1/kPa)**	**n**
-14.8217	-1.73951	1.038	0.410	3.66E-07	0.176	TRUE													
-13.7915	-1.41478	1.577	0.401	1.02E-06	0.243	TRUE													
-14.466	-1.66459	1.648	0.412	5.22E-07	0.189	TRUE													
-14.5292	-1.52549	1.299	0.421	4.90E-07	0.218	TRUE													
-14.0924	-1.59524	1.395	0.416	7.58E-07	0.203	TRUE													
-15.3212	-1.63234	1.018	0.395	2.22E-07	0.195	TRUE													
-13.1203	-1.4699	1.212	0.421	2.00E-06	0.230	TRUE													
-13.5496	-1.72886	1.805	0.380	1.30E-06	0.177	TRUE													
-13.5017	-1.59134	1.713	0.406	1.37E-06	0.204	TRUE													
-14.4403	-1.44534	1.382	0.399	5.35E-07	0.236	TRUE													
-15.0332	-1.70483	1.421	0.409	2.96E-07	0.182	TRUE													
-15.1348	-1.56427	1.134	0.414	2.67E-07	0.209	TRUE													
-14.6309	-1.63416	1.238	0.411	4.42E-07	0.195	TRUE													
-14.1246	-1.49934	1.678	0.392	7.34E-07	0.223	TRUE													
-14.6838	-1.73141	1.820	0.401	4.20E-07	0.177	TRUE													
-14.7511	-1.58798	1.347	0.405	3.92E-07	0.204	TRUE													
-14.3373	-1.656	1.448	0.403	5.93E-07	0.191	TRUE													
-14.9962	-1.43285	1.225	0.396	3.07E-07	0.239	TRUE													
-13.9092	-1.58083	1.262	0.405	9.11E-07	0.206	TRUE													
-14.0069	-1.42877	0.830	0.410	8.26E-07	0.240	FALSE													
-15.3532	-1.69125	1.053	0.407	2.15E-07	0.184	TRUE													
-14.6572	-1.53321	1.434	0.388	4.31E-07	0.216	TRUE													
-15.5314	-1.79405	1.477	0.399	1.80E-07	0.166	TRUE													
-12.72	-1.37449	1.189	0.402	2.99E-06	0.253	TRUE													

OUTPUTS																**INPUT**		
Correlated Random Variates								**Mean Vector**				**Means**				**Arithmetic Transform of Means**		
lnK	**lna**	**n**	**Theta-s**	**Ks**	**a**	**Control Check**		**lnKs**	**lna**	**n**	**Theta-s**	**lnKs**	**lna**	**n**	**Theta-s**	**Ksat (m/s)**	**alpha (1/kPa)**	**n**
-14.8658	-1.69218	1.286	0.401	3.50E-07	0.184	TRUE												
-13.8646	-1.73841	1.034	0.393	9.52E-07	0.176	TRUE												
-14.5036	-1.62512	1.088	0.402	5.03E-07	0.197	TRUE												
-14.5669	-1.4466	1.539	0.406	4.72E-07	0.235	TRUE												
-14.7888	-1.69074	1.265	0.386	3.78E-07	0.184	TRUE												
-14.9565	-1.77936	1.421	0.408	3.20E-07	0.169	TRUE												
-15.0461	-1.62929	1.134	0.414	2.92E-07	0.196	TRUE												
-15.0282	-1.5625	1.107	0.400	2.97E-07	0.210	TRUE												
-14.0544	-1.55644	1.678	0.391	7.88E-07	0.211	TRUE												
-14.6274	-1.45953	1.820	0.401	4.44E-07	0.232	TRUE												
-14.7926	-1.54147	1.622	0.397	3.76E-07	0.214	TRUE												
-14.3762	-1.61608	0.761	0.395	5.71E-07	0.199	FALSE												
-13.7053	-1.46669	1.323	0.411	1.12E-06	0.231	TRUE												
-13.9691	-1.54604	1.489	0.397	8.58E-07	0.213	TRUE												
-14.0589	-1.74194	1.200	0.400	7.84E-07	0.175	TRUE												
-14.0427	-1.63547	1.176	0.386	7.97E-07	0.195	TRUE												
-14.6963	-1.44586	0.605	0.418	4.14E-07	0.236	FALSE												
-15.7724	-1.76977	0.877	0.389	1.41E-07	0.170	FALSE												
-13.3682	-1.37997	1.408	0.394	1.56E-06	0.252	TRUE												
-14.9121	-1.65489	1.522	0.392	3.34E-07	0.191	TRUE												
-14.4023	-1.51769	1.162	0.407	5.56E-07	0.219	TRUE												
-14.9795	-1.7498	1.202	0.361	3.12E-07	0.174	TRUE												
-15.0723	-1.61188	1.758	0.384	2.85E-07	0.200	TRUE												
-14.5927	-1.67308	0.945	0.380	4.60E-07	0.188	FALSE												

OUTPUTS																INPUT		
Correlated Random Variates								Mean Vector				Means				Arithmetic Transform of Means		
lnK	lna	n	Theta-s	Ks	a	Control Check		lnKs	lna	n	Theta-s	lnKs	lna	n	Theta-s	Ksat (m/s)	alpha (1/kPa)	n
-15.59	-1.96494	1.505	0.412	1.70E-07	0.140	TRUE												
-14.2421	-1.60641	1.558	0.384	6.53E-07	0.201	TRUE												
-14.3104	-1.44224	1.250	0.390	6.10E-07	0.236	TRUE												
-13.7346	-1.52651	1.345	0.388	1.08E-06	0.217	TRUE												

Appendix F – RESPONSE TO ENERGY*SOLUTIONS* REPORT ON IMPACTS OF FREEZE-THAW ON HYDRAULIC CONDUCTIVITY OF CLAY BARRIERS AT THE CLIVE, UTAH FACILITY

by

Craig H. Benson, PhD, PE, NAE
Wisconsin Distinguished Professor of Civil & Environmental Engineering and Geological Engineering, University of Wisconsin-Madison

F.1 Introduction

In a report dated February 6, 2015, Energy*Solutions* has evaluated data and drawn conclusions regarding the potential impacts of freezing and thawing on the hydraulic conductivity of clay barriers used in the final covers at Energy*Solutions* Low-Level Radioactive Waste disposal facility in Clive, Utah. In Section 4 of this report, Energy*Solutions* concludes:

> *…it is significant to note that site-specific data obtained from Energy Solutions' use of compacted clays for embankment liners and cover barrier layers do not mirror the impact of the freeze/thaw on hydraulic conductivity predicted in Benson et al. (2011). Therefore, Clive's site-specific observations should be preferentially weighted over Benson et al.'s national ranges in the Division's approval of the demonstration of comliant-performance* [sic] *of the CAW's evapotranspirative cover…*

Energy*Solutions* draws this conclusion based on comparisons of hydraulic conductivity measurements made during construction of their clay barriers and after the barriers were been exposed to winter weather. Energy*Solutions* also makes comparisons between dry densities measured during construction and those after exposure to winter weather. Based on these comparisons, Energy*Solutions* concludes that the hydraulic conductivity decreased after exposure to winter weather, and the dry density increased after exposure to winter weather.

F.2 Concerns

F.2.1 Insufficient Information on Freezing and Thawing

The information provided by Energy*Solutions* is not sufficient to determine if their clay barriers were exposed to conditions that caused freezing within the barrier, and to what depth. Each of the sites examined by Benson et al. (2011) was instrumented with nests of thermocouples, allowing an assessment of temperature versus depth and providing the opportunity to determine if freezing occurred at depth. This type of assessment is not possible with the information provided in the report submitted by Energy*Solutions*.

If freezing of the Energy*Solutions* clay barriers did not occur during the period over which the barriers were evaluated, or freezing occurred only at the surface of the clay barriers, then a change in hydraulic conductivity would not be expected. However, this does not imply that freezing and thawing will not occur during the service life of the facility, or that the hydraulic conductivity will not change in response to a freezing and thawing event in the future. Evaluating this impact of this change in hydraulic conductivity, if possible for current and future climatic conditions, is important to assess the long-term efficacy of the barrier.

F.2.2 Inconsistency with Existing Knowledge Base

If freezing and thawing did occur in the clay barriers at depth at the Clive site, then the hydraulic conductivity data provided by Energy*Solutions* are highly unusual and suspect and will require further evaluation to determine if the data are valid and applicable. Many data have been compiled on the impacts of freezing and thawing on clay barrier materials over the past 35 years. These data have shown universally that freezing and thawing causes an increase in the hydraulic conductivity of soil barriers constructed with natural clayey soils that have liquid limits and plasticity indices falling in the CL-CH zone of the plasticity chart. The findings reported by Benson et al. (2011) are consistent with the broader body of evidence on this issue.

Many of the early studies on this issue were conducted to understand how freezing and thawing might affect radon barriers for covers used over disposal facilities for uranium mill tailings [11e.(2) sites], some of which are similar to the final covers deployed at the Clive disposal facility. Othman et al. (1994) published a state-of-the-art review illustrating this behavior approximately two decades ago. American Society for Testing and Materials (ASTM) Method D6035-13 was developed based on the findings in Othman et al. (1994) and other studies to provide a standard method to evaluate the impact of freezing and thawing on clayey barrier materials. At a minimum, Energy*Solutions* should conduct tests using ASTM Method D6035-13 on specimens prepared at compaction conditions similar to those achieved at Clive facility and at effective stresses similar to the effective stress expected in the cover at the Clive facility. These tests would illustrate whether the clayey barrier soil used at the Clive facility has properties in the context of freezing and thawing that are indeed different from the broad range of clayey barrier soils that have evaluated for the impacts of freezing and thawing over the past 35 years.

F.2.3 Field Testing Methodology

The report submitted by Energy*Solutions* provides insufficient information to assess the applicability of the field tests that were conducted to evaluate the hydraulic conductivity of the barriers at the Clive disposal facility. No test method from ASTM (or other recognized independent standardization body) is cited on the data sheets or described in the report. Methods recognized by industry as reliable for field measurement of the hydraulic conductivity of compacted clayey barriers are the sealed double-ring infiltrometer test (ASTM D5093-02), the borehole infiltration test with a 300-millimeter (mm)-diameter casing (ASTM D6391-11), or a laboratory hydraulic conductivity test conducted using ASTM D5084-10 on large-scale undisturbed block samples having a diameter no less than 300 mm collected using the methods in ASTM D7015-13. Information on the data sheets titled “Field Permeability Test” that were included in the appendix to the report submitted by Energy Solutions (2015) is not consistent with data collected from any of the aforementioned industry-standard test methods.

The short duration of the field tests, each of which was conducted for no more than 8 minutes, also raises doubts about the efficacy of the field test method that was employed. Most field tests take hours at a minimum, and an accurate measurement of very low hydraulic conductivities such as those reported by Energy*Solutions* generally takes days to weeks. Accordingly, the representativeness of a field measurement made in 8 minutes is suspect.

Thus, while field measurements may have been made to document the condition of the clayey barriers at the Clive facility after construction, and to evaluate conditions after winter exposure, the test method appears dubious. Defining the test method and demonstrating that hydraulic conductivities obtained with this method are representative of field scale conditions would be needed for the data collected by Energy*Solutions* to be given weight in an evaluation of the evapotranspirative cover.

F.2.4 Changes in Dry Density

Energy*Solutions* reports that the dry density of their clayey barriers increased between the end of construction and testing after winter exposure. This is a common occurrence in soils exposed to freezing and thawing, and is attributed to thaw consolidation (Chamberlain and Gow 1979). Thus, observing an increase in dry density does not preclude an absence of change in hydraulic conductivity due to freezing and thawing. Indeed, Benson et al. (1995) show that changes in dry density are a poor surrogate for changes in hydraulic conductivity due to freezing and thawing. They found no correspondence between changes in hydraulic conductivity and changes in dry density for clayey barriers before and after freezing and thawing.

Energy*Solutions* also reports increases in dry density exceeding 100 percent. An increase in dry density this large is physically impossible, as it implies that all of the void space in the soil was eliminated during exposure to winter weather.

F.2.5 Other Pedogenic Processes

Regardless of whether freezing and thawing occurs in the clayey barriers used at the Clive disposal facility, other pedogenic processes, such as wet-dry cycling and biota intrusion, will alter the hydraulic conductivity of clayey barriers used in the evapotranspirative cover. These processes were present in the barrier systems evaluated in Benson et al. (2011) and were equally important, if not more important, than freezing and thawing. These processes are present in final covers at essentially all disposal sites in North America. Much more evidence would be needed to justify that conditions at the Clive disposal facility are truly unique and different from those at the sites described in Benson et al. (2011).

F.3 References

Benson, C., Albright, W., Fratta, D., Tinjum, J., Kucukkirca, E., Lee, S., Scalia, J., Schlicht, P., Wang, X. (2011), Engineered Covers for Waste Containment: Changes in Engineering Properties & Implications for Long-Term Performance Assessment, NUREG/CR-7028, Office of Research, U.S. Nuclear Regulatory Commission, Washington.

Benson, C., Chamberlain, E., Erickson, A., and Wang, X. (1995), Assessing Frost Damage in Compacted Clay Liners, *Geotech. Testing J.*, 18(3), 324-333.

Chamberlain, E. and Gow, X. (1979), Effect of Freezing and Thawing on the Permeability and Structure of Soils, Engineering Geology, 73-92.

Energy*Solutions*, LLC (ES), 2015, “RML UT2300249 – Updated Site Specific Performance Assessment Supplemental Response to Round 1 Interrogatories,” February 6.

Othman, M., Benson, C., Chamberlain, E., and Zimmie, T. (1994), Laboratory Testing to Evaluate Changes in Hydraulic Conductivity Caused by Freeze-Thaw: State-of-the-Art, *Hydraulic Conductivity and Waste Containment Transport in Soils, STP 1142*, ASTM, S. Trautwein and D. Daniel, eds., 227-254.

Appendix G – INTERPRETING THE HUNTSMAN AGREEMENT

OFFICE OF THE ATTORNEY GENERAL, STATE OF UTAH MEMORANDUM

TO: Helge Gabert, Project Manager
EnergySolutions Depleted Uranium Performance Assessment

FROM: Laura Lockhart, Assistant Attorney General
Utah Attorney General's Office

DATE: April 6, 2015

RE: Interpreting the Huntsman Agreement

This memo is in response to your request for an explanation of how the Huntsman Agreement (attached) would be enforced and what limitations it imposes on the State of Utah. I should note that this memo includes my legal advice to you, but is not a formal Attorney General's Office opinion and does not reflect any determination made by the Attorney General.

A. Background: History of the Huntsman Agreement

The Huntsman Agreement ("Agreement"), reflected a policy determination by the administration of Governor Jon Huntsman that there should be an upper limit to the amount of waste that Energy*Solutions* would be allowed to dispose of. This policy determination came at a time when one Energy*Solutions* proposal for expansion beyond its borders had just been defeated,[1] and another proposal had been submitted for approval to increase disposal capacity by combining two existing cells into the Combined Class A Cell referred to in paragraph 1 of the Agreement.

As described in paragraph 3 of the Agreement, the Huntsman Administration had been considering turning to the Northwest Interstate Compact on Low-Level Radioactive Waste ("Compact") to enforce its waste limitations. This would likely have resulted in a dispute because, as can be inferred from later litigation described below, Energy*Solutions* believed that the Compact's authority did not extend to waste disposal at Energy*Solutions*. Energy*Solutions* and the Huntsman Administration entered into negotiations to see if they could agree on a waste cap that would allow both sides to avoid litigation.

The negotiations resulted in the March 15, 2007 Huntsman Agreement, under which the parties agreed that Energy*Solutions* could convert all of the remaining capacity in a disposal cell

[1] Energy*Solutions*' proposal to expand its boundaries was stopped by the Utah Legislature with the passage of SB 155 during the 2007 General Session. That bill required approval of the Legislature and the Governor before the boundaries of an existing facility could be expanded. Energy*Solutions* has not sought approval for a boundary expansion.

Memorandum to Helge Gabert
April 6, 2015
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for 1 le.(2) byproduct waste - a waste that is generally of very low radioactivity, but that does not fit the definition of low-level radioactive waste - to a higher level Class A waste disposal facility. In exchange, Energy*Solutions* agreed to limit total disposal to the combined currently-approved Class A and 11e.(2) converted amounts, and also agreed not to seek authority to dispose of Class B or Class C waste.

The parties were unable to avoid litigation about the Compact's authority for very long, however. In 2008, the Huntsman Administration objected to Energy*Solutions*' plan to dispose of imported Italian radioactive waste. The Huntsman Administration was in the process of bringing that issue to the Compact to request that it prohibit foreign waste disposal when Energy*Solutions* brought a lawsuit against the Compact seeking a declaratory judgment that the Compact had no authority over the Energy*Solutions* disposal site. The State of Utah intervened in the lawsuit. After a loss at the federal District Court level, the Compact and the State of Utah won in the 10th Circuit Court of Appeals. It is now clear that the Compact does have authority to control waste disposal at Energy*Solutions*. See *EnergySolutions v. State of Utah*, 625 F.3d 1261 (10th Cir. 2010).

B. <u>Background: History of Approved Waste Disposal Volume at Energy*Solutions*</u>

There were three cells authorized for disposal of low-level radioactive waste at the time of the Huntsman Agreement: the Class A, Class A North and Mixed Waste Cells.[2] As described above, the Huntsman Agreement also authorized conversion of a cell that had been authorized for disposal of 11e.(2) waste to Class A waste disposal.

In 2006, Energy*Solutions* proposed to consolidate the Class A and Class A North cells into a single Class A West cell. At about the same time, it also proposed to expand the Mixed Waste Cell. Both of those changes were approved in one license amendment in 2012. In order to remain consistent with the terms of the Huntsman Agreement, the Division of Radiation Control agreed to move some of the unused capacity allowed under the agreement from the 11e.(2) cell into both the new Class A West cell and the Mixed Waste Cell.

[2] All of the information in Part B may be found in the appropriate license and permit amendment files located in the Divisions of Radiation Control and Solid and Hazardous Waste for these licenses and permit: Radioactive Material License UT 2300249 (DRC); Byproduct Material License, UT 2300478 (DRC); and Part B RCRA Mixed Waste Permit (DSHW).

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C. <u>Enforceability and Scope of the Huntsman Agreement</u>

1. Is the Huntsman Agreement enforceable?

The remedy for a violation of the terms of the Huntsman Agreement by Energy*Solutions* is spelled out in paragraph 3 of the Agreement itself: the State can go to the Compact and seek enforceable limitations. It should be noted that this is a more certain remedy now than it was at the time the Agreement was executed since the Compact has since been judicially determined to have authority over the Energy*Solutions* facility. Approval by the Compact would still be required, however.

2. Did the Huntsman Agreement bind future administrations to the waste volume limits in the Agreement?

No it did not. The only commitment made by Governor Huntsman in the Agreement, in paragraph 3, is that the Governor would refrain from seeking authority from the Compact to impose new disposal volume restrictions on Energy*Solutions* if the facility met the Agreement's restrictions. The Agreement did not affirmatively require the State of Utah to request a limitation from the Compact if Energy*Solutions* failed to meet the Agreement restrictions.[3] This conclusion is even more clear in light of this provision in the Agreement:

> Except for the commitments made by the Governor pursuant to this agreement, nothing in this agreement shall alter or limit the authority or legal rights of the State of Utah, the Compact, the Utah Board of Radiation Control, or the Board's Executive Secretary.

Huntsman Agreement, ¶ 5. Future administrations are therefore free to agree to different volume limitations or to end any limitations.

There are also no requirements from other sources that would prevent a different administration from effecting a different policy. There is no disposal volume limitation in the Compact policies or regulations[4], and, other than the geographic boundary limitation found in Utah Code Ann. § 19-3-105(3) and (8), there is no disposal volume limitation in state law.

[3] Because the Huntsman Agreement does not seek to tie the hands of later administrations, I have not evaluated an administration's authority to do so.

[4] See Compact policies at http://www.ecy.wa.gov/nwic/policy.htm.

Attachment to Lockhart April 6, 2015 Memo "Interpreting the Huntsman Agreement"

AGREEMENT

This agreement is entered into by and between the Governor of the State of Utah and EnergySolutions, LLC, and any successor or assignee ("EnergySolutions") as follows:

1. EnergySolutions will promptly withdraw the Combined Class A Cell license amendment currently pending before the Utah Board of Radiation Control and its Executive Secretary. EnergySolutions may complete the required licensing process for conversion of the remaining already licensed unused capacity (the "converted already licensed capacity") of the currently-licensed 11e.(2) Cell to a Class A Cell (the "Converted Class A Cell"), and upon successfully meeting all technical and legal requirements, utilize the converted already licensed capacity for the disposal of low-level radioactive waste in the Converted Class A Cell.

2. EnergySolutions and the State of Utah reiterate their commitment that they do not support Class B or C low-level radioactive waste or radioactive waste having a higher radionuclide concentration than the highest radionuclide concentration allowed under licenses existing on February 25, 2005, being disposed in the State of Utah as outlined in Utah Code Annotated Section 19-3-103.7.

3. For so long as EnergySolutions refrains from applying for a license, license amendment, or license renewal for disposal of low-level radioactive waste beyond the currently-licensed low-level radioactive waste cell volumes, which were licensed as of May 1, 2006, and the Converted Class A Cell, the Governor agrees to refrain from making, and shall not permit his designee to make, any request to the Northwest Interstate Compact on Low-Level Radioactive Waste Management (the "Compact") regarding low-level radioactive waste volumes for receipt by EnergySolutions, except as necessary to facilitate the Converted Class A Cell volume, or to initiate or support action to limit the volume of low-level radioactive waste on Section 32, Township 1S, Range 11W, of EnergySolutions' Clive Facility.

4. Nothing in this agreement shall be construed as an admission by EnergySolutions that the Compact has jurisdiction over its operations or facilities or a waiver of EnergySolutions' rights of recovery, if any, for unlawful taking without due process of law, impairment of third-party contracts, violation of vested property rights, or similar claims, based on future actions of the State of Utah or the Compact. Notwithstanding the foregoing, this agreement shall not be used as the basis for any claims against the State of Utah or the Compact.

5. Except for the commitments made by the Governor pursuant to this agreement, nothing in this agreement shall alter or limit the authority or legal rights of the State of Utah, the Compact, the Utah Board of Radiation Control, or the Board's Executive Secretary.

This Agreement will take effect upon the signatures of the parties.

Jon M. Huntsman, Jr. — March 15, 2007
Governor
State of Utah
Date

R. Steve Creamer — 3/15/07
Chief Executive Officer
EnergySolutions, LLC
Date

Appendix H – HISTORICAL AND CURRENT UNDERSTANDING ABOUT THE DEEP AQUIFER IN THE VICINITY OF THE PROPOSED FEDERAL CELL

There are a few wells drilled to about 100 feet inside Section 32 (the location of the proposed Federal Cell at the Energy*Solutions* Clive site). Below that depth even less is known. The deepest nearby boring is the Broken Arrow boring in the southeast quarter of Section 29, found about 500 feet north of Section 32.

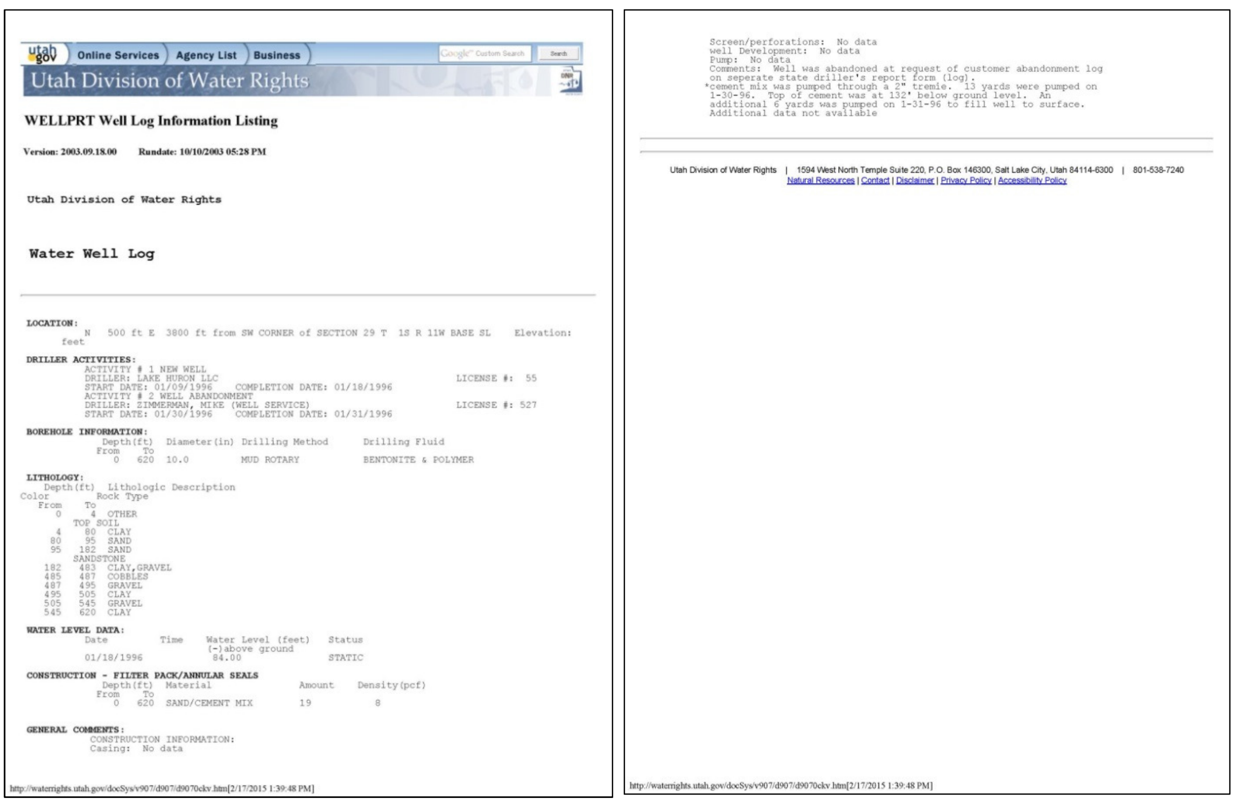
In the early 1990s, there were only three well nests to measure vertical hydraulic gradients across the 100-foot depth interval (i.e., well nests at GW-19B, I-1-100, and I-3-100). Well nest GW-19B was located in the extreme southwest corner of Section 32, while well nests I-1-100 and I-3-100 were located a few hundred feet south and a few hundred feet north of the Mixed Waste Cell, respectively (Bingham 1991, Figure 10). At that time, the shallow aquifer appeared to be flowing in a northerly direction (Bingham 1991, Figure 14); however, no potentiometric contour map was prepared by Energy*Solutions* for the 100-foot deep system at that time. The Bingham (1991) report provides data on the freshwater equivalent heads for the three 100-foot aquifer monitoring wells, which ranged from 4,249.81 feet above mean sea level (ft-amsl) (I-3-100) to 4,251.63 ft-amsl (I-1-100). These deeper aquifer heads were higher than the 30-foot shallow aquifer's freshwater equivalent water levels by about 1 foot or more, as summarized in the following table (Bingham 1991, pp. A-171 and A-172).

Table H-1 – Vertical Groundwater Flow Direction, Nested Wells

Well	2/26/91 Event			5/10/91 Event		
	FWeqGW Elevation (ft)	Delta Head (ft)	Flow Direction	FWeqGW Elevation (ft)	Delta Head (ft)	Flow Direction
GW-19A	4,249.03			4,248.89		
GW-19B	4,251.44	+2.41	UP	4,249.64	+0.75	UP
I-1-30	4,249.16			4,248.95		
I-1-100	4,251.63	+2.47	UP	4,251.32	+2.37	UP
I-3-30	4,248.72			4,248.74		
I-3-100	4,249.81	+1.09	UP	4,249.92	+1.18	UP

However, since the time of the 1991 report, the flow directions in several nested well pairs reversed. The direction of flow near these nested well pairs is down. This is ascribed to groundwater mounding that took place when surface water penetrated the silty clay and clayey silt soils near the surface and moved down to the water table. The vulnerability of the water table to such flows indicates a need to consider all hydraulic gradients in the area carefully.

In January 1996, the Energy*Solutions* (then Envirocare) contractor, Broken Arrow, drilled a 620-foot boring in the southeast quarter of Section 29, 500 feet north of Section 32. The driller reported a static water level at 84 feet below ground surface (bgs) (Figure H-1). From the location description provided to the Utah Division of Water Rights, the Utah Division of Radiation Control (DRC) staff estimated the elevation of this drilling location from the United States Geological Survey 7.5-minute Aragonite Quadrangle topographic map to be about 4,281 ft-amsl. If correct, then the driller report indicates that the static water level in the very deep aquifer (+ 500 ft bgs) in 1996 had an elevation of 4,197 ft-amsl. From this information and information presented in Bingham (1991), DRC staff generated a preliminary hydrogeologic cross-section to illustrate these 1992–1996 data (Figure H-2). From the Broken Arrow boring, it appears that the 100-foot Energy*Solutions* monitoring wells may have been installed in a sand layer that extends between about 80 and 182 feet bgs, which is referred to as the Intermediate Aquifer in the DRC cross-section. The coarsest geologic deposits, and presumably the highest productive aquifer at Clive, as reported in the Broken Arrow boring appear to be at depths of about 485–545 feet bgs. On the attached cross-section, DRC staff have interpreted this deepest interval to be the source of the static water level reported by the driller in 1996. If the Broken Arrow information is reliable, the 500+ foot aquifer at Clive would have a static head that is about 53 feet lower in 1996 than the measurements made in I-3-100 in 1992. This would equate to a downward hydraulic gradient of about 0.13 foot/foot; which is about 260 to 650 times higher than the horizontal gradient reported in Section 32 by Bingham (1991), Table 1 (0.0002 to 0.0005feet/feet). This strongly implies the potential for downward flow to the deeper aquifer system.



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Utah Division of Water Rights

WELLPRT Well Log Information Listing

Version: 2003.09.18.00   Rundate: 10/10/2003 05:28 PM

Utah Division of Water Rights

Water Well Log

```
LOCATION:
          N   500 ft E  3800 ft from SW CORNER of SECTION 29 T  1S R 11W BASE SL    Elevation:
     feet

DRILLER ACTIVITIES:
          ACTIVITY # 1 NEW WELL
          DRILLER: LAKE HURON LLC                                         LICENSE #:  55
          START DATE: 01/09/1996    COMPLETION DATE: 01/18/1996
          ACTIVITY # 2 WELL ABANDONMENT
          DRILLER: ZIMMERMAN, MIKE (WELL SERVICE)                         LICENSE #: 527
          START DATE: 01/30/1996    COMPLETION DATE: 01/31/1996

BOREHOLE INFORMATION:
             Depth(ft)  Diameter(in) Drilling Method      Drilling Fluid
            From    To
               0    620  10.0          MUD ROTARY           BENTONITE & POLYMER

LITHOLOGY:
   Depth(ft)  Lithologic Description
Color        Rock Type
  From     To
     0      4  OTHER
        TOP SOIL
     4     80  CLAY
    80     95  SAND
    95    182  SAND
        SANDSTONE
   182    483  CLAY,GRAVEL
   485    487  COBBLES
   487    495  GRAVEL
   495    505  CLAY
   505    545  GRAVEL
   545    620  CLAY

WATER LEVEL DATA:
          Date         Time    Water Level (feet)   Status
                               (-)above ground
          01/18/1996            84.00               STATIC

CONSTRUCTION - FILTER PACK/ANNULAR SEALS
             Depth(ft)  Material               Amount    Density(pcf)
            From    To
               0    620  SAND/CEMENT MIX       19           8

GENERAL COMMENTS:
           CONSTRUCTION INFORMATION:
           Casing:  No data
           Screen/perforations:  No data
           well Development:  No data
           Pump:  No data
           Comments:  Well was abandoned at request of customer abandonment log
           on seperate state driller's report form (log).
          *cement mix was pumped through a 2" tremie.  13 yards were pumped on
           1-30-96.  Top of cement was at 132' below ground level.  An
           additional 6 yards was pumped on 1-31-96 to fill well to surface.
           Additional data not available
```

Utah Division of Water Rights | 1594 West North Temple Suite 220, P.O. Box 146300, Salt Lake City, Utah 84114-6300 | 801-538-7240
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http://waterrights.utah.gov/docSys/v907/d907/d9070ckv.htm[2/17/2015 1:39:48 PM]

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Figure H-1 – Borelog for Broken Arrow well

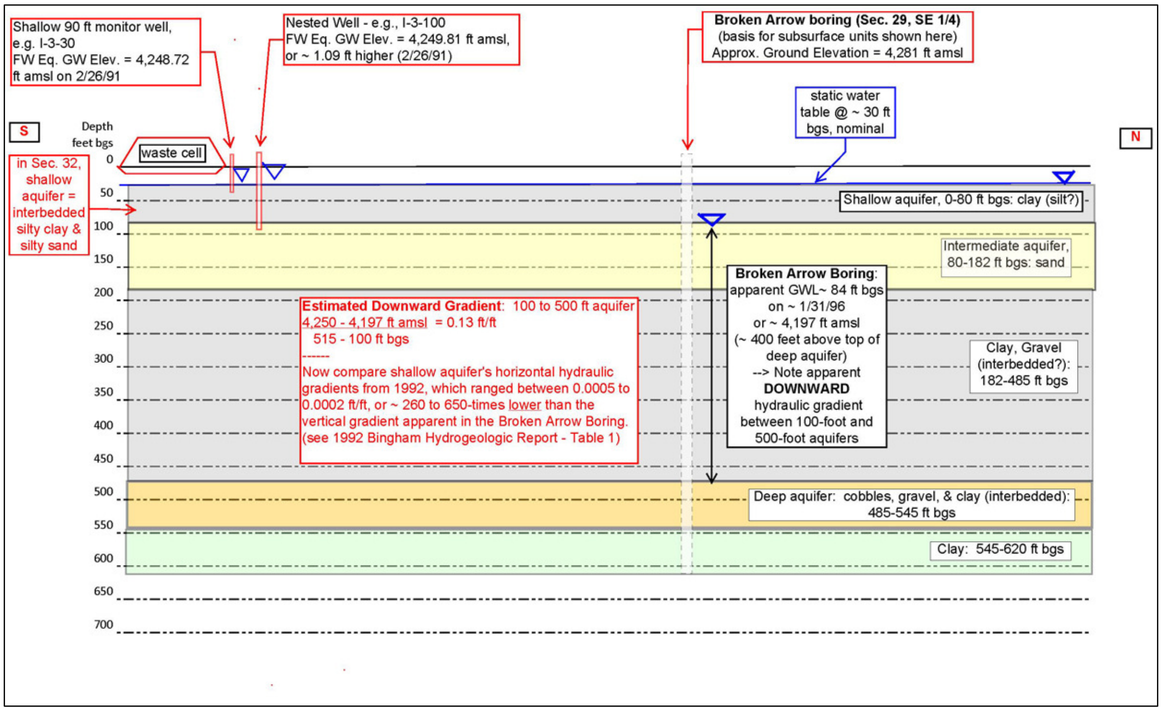
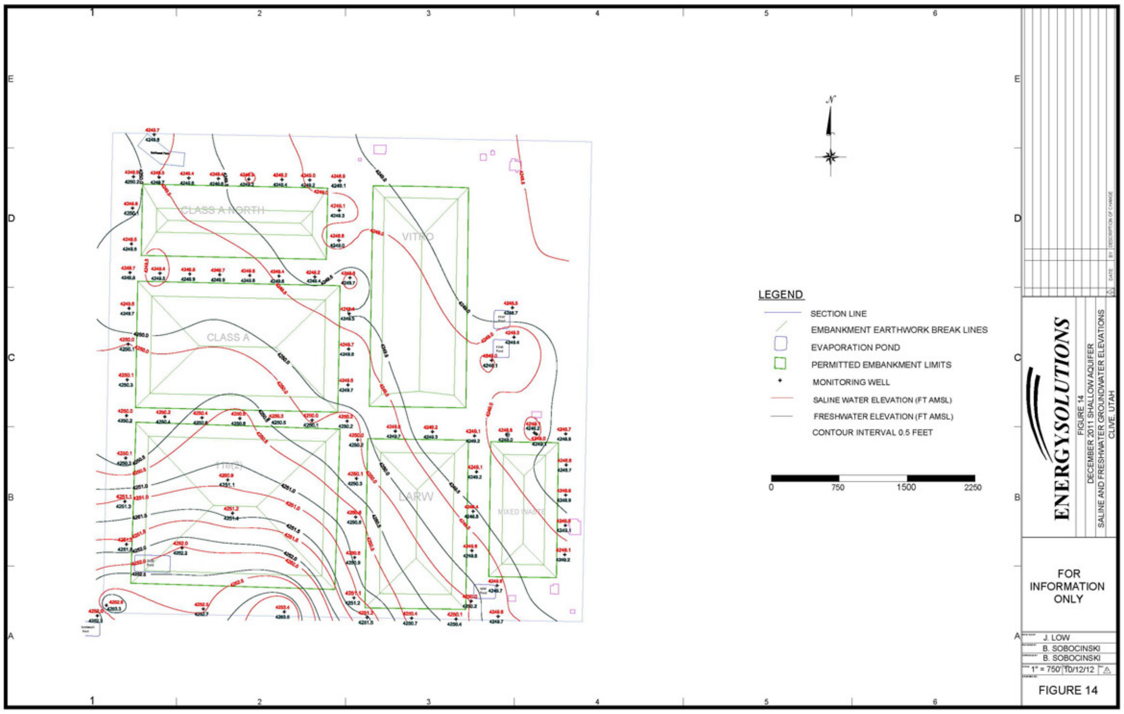


Figure H-2 – Hydrogeologic cross-section

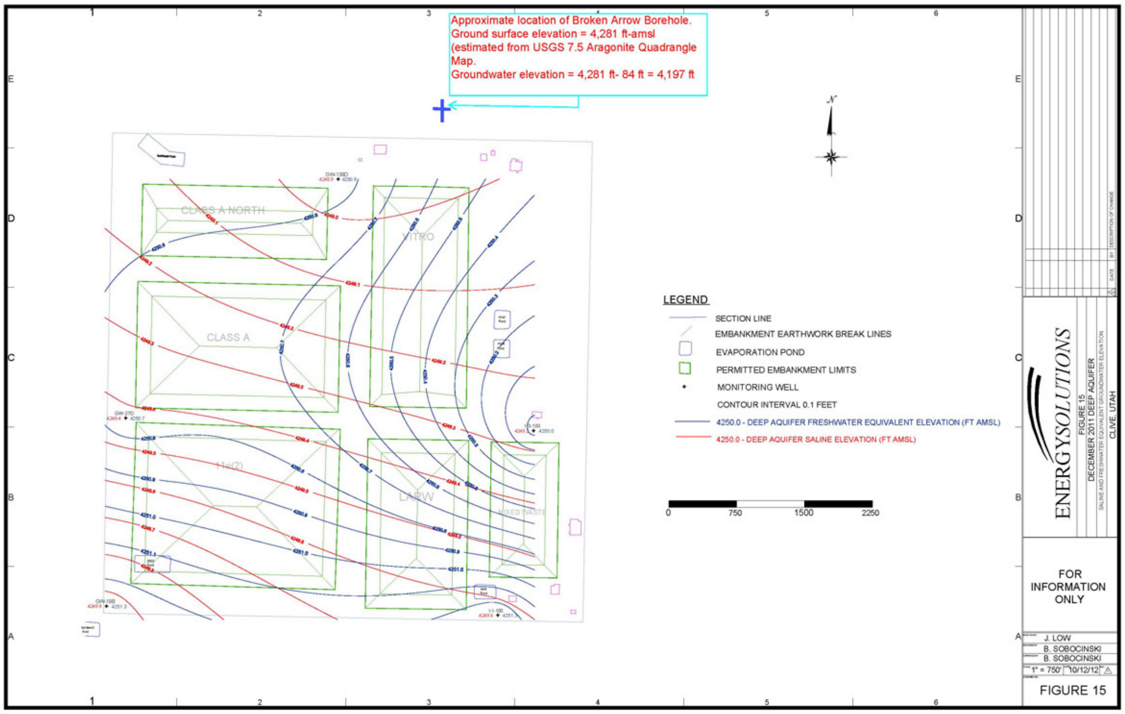
Today, little more is known about the 100-foot deep system, with five well nests across Section 32 with data as late as December 2011. From these, Energy*Solutions* has measured vertical gradient at approximately all four margins of Section 32 in wells GW-19B and GW-27D (western margin), GW-139 (northern margin), I-1-100 (southern margin), and I-3-100 (eastern margin). Data from these five well nests are found in Table 6 of the December 2, 2013, Energy*Solutions* revised hydrogeologic report, version 3.1 (hereafter "the 2013 Energy*Solutions* HG Report"). Figure H-3 reproduces Figure 15 from this Energy*Solutions* report. However, note that the I-3-100 well nest has since been abandoned to allow recent expansion of the Mixed Waste disposal unit (personal communication, Charlie Bishop, DRC to Loren Morton).



Source: Energy*Solutions* (2013), Figure 15.

Figure H-3 – Potentiometric surface of the intermediate aquifer (originally termed the deep aquifer by Energy*Solutions*) (December 2011)

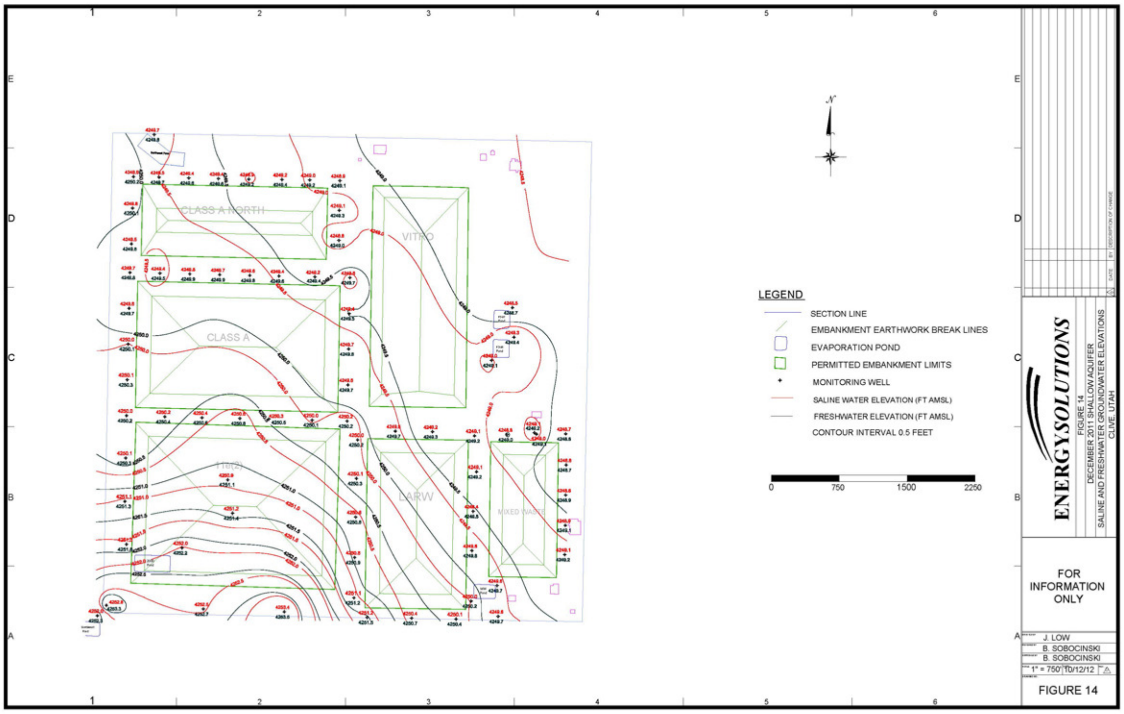
The two newest 100-foot wells, GW-27D (located off the northwest corner of the proposed Federal Cell), and GW-139 (found off the northeast corner of the CAN Cell, now Class A West Cell), are screened at depths of 85–100 and 80.5–95.5 feet bgs, respectively (see ES 2013, Figure15, and Appendix A). In the 2013 Energy*Solutions* HG Report, Figure 15 (see Figure H-3), groundwater flow in the 100-foot aquifer appears is to be to the east; however, a southerly component may exist in places, based on equal freshwater equivalent heads found in wells GW-19B and I-1-100 on the south margin of Section 32 (where both had heads of 4,251.3 ft-amsl). Also note that the easterly groundwater flow in Energy*Solutions* Figure 15 is directly opposed to the assumption that the Cedar Mountains are the local source of intermediate groundwater recharge (which should induce groundwater flow in a westerly direction). Also of interest is that the 100-foot aquifer's freshwater equivalent head in new well GW-139D (4,250.9 ft-amsl) near the north margin of Section 32 is very nearly equal to the head found in well GW-27D (4,250.7 ft-amsl) near the western margin—reinforcing the easterly flow interpretation for the 100-foot system. Furthermore, there is a 53-foot decrease in head between the Section 32 wells and the Broken Arrow boring, which is very near the facility, as annotated on a DRC-modified version of Energy*Solutions* (2013) Figure 15 (see Figure H-4). The 53-foot decrease in head between the Section 32 wells and the Broken Arrow boring indicate a downward gradient and deserve additional investigation to fully characterize subsurface groundwater flow conditions for the 500+ foot deeper aquifer that would potentially be used by a future intruder. Hydraulic interconnection of the three aquifers possible at Clive also deserves attention.



Source: Modified by DRC from Energy*Solutions* (2013).

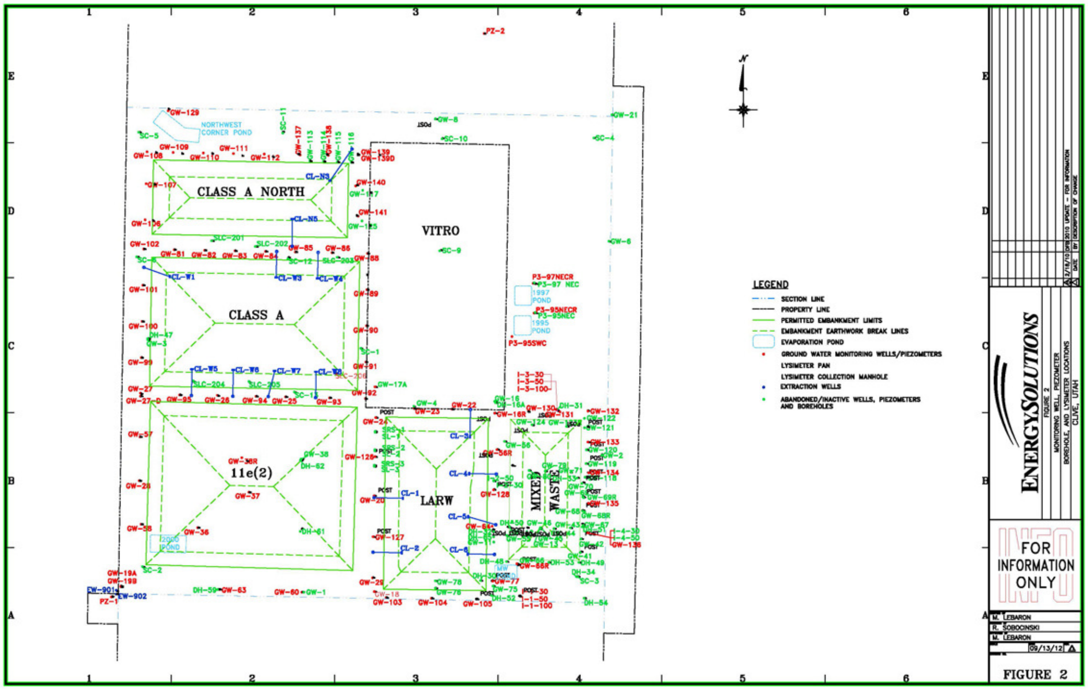
Figure H-4 – Potentiometric data from Broken Arrow well (modified from ES 2013)

Figure 14 of the 2013 ES HG Report (reproduced here as Figure H-5) shows both the shallow aquifer's freshwater equivalent heads and the saline heads from December 2011. This figure suggests shallow groundwater flow was to the northeast. This direction may be an effect of the groundwater mound seen near wells GW-19A and GW-60. The location of these and other Energy*Solutions* wells are shown in Figure H-6 (ES 2013, Figure 2).



Source: Energy*Solutions* (2013), Figure 14.

Figure H-5 – Shallow aquifer's freshwater and saline heads (December 2011)



Source: Energy*Solutions* (2013), Figure 2.

Figure H-6 – Location of shallow monitoring wells

In conclusion, the current understanding of the hydraulics and vertical interconnection of the Clive aquifers is very limited. From the cryptic information derived from the Broken Arrow boring, there may very well be three different aquifers at Clive, instead of the two that have been assumed thus far. Without characterization of these deeper strata and determination of their hydraulic properties, The Utah Department of Environmental Quality may be hampered in making defensible conclusions about long-term fate and transport of contaminants from the proposed Federal Cell, and possible future exposure to inadvertent intruders.

UAC R313-25 requires investigation of all aquifers in the area. For example, as can be inferred from UAC R313-25-3(6) and UAC R313-25-8(1), various features of deeper aquifers at the site must be investigated including the identity and presence of the aquifers, their geologic characteristics, their geochemical characteristics, their geotechnical characteristics, their hydrologic characteristics, and the quality of associated groundwaters. These two rules are as follows:

(6) The plan approval siting application shall include the results of studies adequate to *identify the presence of ground water aquifers in the area* of the proposed site and to *assess the quality of the ground water of **all** aquifers identified in the area* of the proposed site. [emphasis added]

and

(1) A description of the natural and demographic disposal site characteristics shall be based on and determined by disposal site selection and characterization activities. The description shall include *geologic, geochemical, geotechnical, hydrologic*, ecologic, archaeologic, meteorologic, climatologic, and biotic features of the disposal site and vicinity. [emphasis added]

It is noted that disposal site characterization activities are needed to develop the required description. Similarly, UAC R313-25-27(1) states that "the applicant shall obtain information about the ecology, meteorology, climate, hydrology, geology, geochemistry, and seismology of the disposal site."

In light of these limitations, if we are to move forward with publication of a safety evaluation report for the depleted uranium performance assessment model report, before additional characterization data become available for the deeper aquifer(s), conservative scenarios should be used to estimate long-term contaminant distribution in the subsurface and human exposure that might result. Because of these concerns, Condition 7 has been added as a condition for any license amendment (see Section 6.2.7 of the SER); namely, that the Licensee shall develop and implement a program to provide more detailed hydrogeologic knowledge of the shallow unconfined aquifer and deeper confined aquifer.

References

Bingham Environmental, 1991. "Hydrologic Report Envirocare Waste Disposal Facility, South Clive, Utah." October 9, 1991.

EnergySolutions (ES), 2012. "Groundwater Quality Discharge Permit (GWQDP) No. UGW450005, Part I.H.24: Submittal of Revised Hydrogeologic Report" (CD12-0298), November 28.

EnergySolutions (ES), 2013. "Revised Hydrogeologic Report – Waste Disposal Facility Clive, Utah," Version 3.1, December 2.