CHAPTER 2 RAIs

RAI 2-33-S: Justify why the material properties, as given in Table 5.3 of Report No. HI-2188143, Revision 1, "HI-STORE Bearing Capacity and Settlement Calculations," are appropriate to represent the materials at the proposed site.

Clarify why the value assigned to some geotechnical parameters is appropriate for the site. For example:

1) Table 5.3 of the revised report gives a friction angle for the Residual Soil at the site as 54°. This is an extremely high value even for most of the hard, igneous rock and certainly for a soil. Appendix C of Report No. HI-2188143, Revision 1, "Bearing Capacity and Settlement Calculation," has used a formula to calculate the friction angle φ from EPRI (Kuhlhaway and Main, 1990):

$$\varphi = 54 - 27.6034\, e^{[-0.0014 \times (N_1)_{60}]}$$

As a function of the corrected Standard Penetration Test blow count $(N_1)_{60}$. Appendix C shows that (N_1) values vary from 58 to 173; however, the calculated value of ϕ remains constant 54° irrespective of $(N_1)_{60}$ values. Provide the appropriate friction angle of the Residual Soil. Additionally, provide the correct source of this equation if it is not in the referenced EPRI document

2) In the revised report, the preconsolidation stress σ_p of the Chinle Formation is taken as the value estimated in sample SW2, obtained at depth of 101 ft below the ground surface. Provide the rationale for using the measured consolidation properties from sample SW2 but not from SW1. The estimated over-consolidation ratio from only SW2 sample seems very high. Provide the rationale for the estimated values of the preconsolidation stress and the over-consolidation ratio.

3) Provide a rationale for why the measured consolidation properties in Chinle mudstone at a depth of 101 ft from the surface (sample SW2) would be appropriate for consolidation settlement in Chinle clay (lean clay or CL) formation near the surface.

4) Page A9 of the revised report states that *"the Chinle Formation mudstone section is considered bedrock. Also, the full depth of the Chinle is considered in the calculation*

Holtec Response:

The geotechnical parameters and their assigned values used to represent the proposed site are clarified below.

1) Upon review, it appears that the equation in the calculation was cited incorrectly. This equation is not used in our analyses developed for this RAI response. Based on the boring log descriptions of the Residual soil, the previous use of 54 degrees for friction angle and a high value of cohesion are incorrect.

   In the latest revision to Holtec Report HI-2188143, the soil friction angle for the Residual soil is determined using Figure 4-12 of Kulhaway and Mayne (1990). The calculation also now includes a small value of drained cohesion to account for the plasticity described within the material.

The Residual Soil classifies as Sandy Clay or Clayey Sand. Because of the low water content and unsaturated insitu condition of the Residual Soil, it is appropriate to use drained strength parameters for this material. A friction angle of 44 degrees corresponds to the upper limit of the correlation presented in Figure 4-12 of Kulhawy and Mayne, and it is a reasonable friction angle for this material. Due to the clay content of this soil, a small drained cohesion intercept of 200 psf is also reasonable. Thus, a drained friction angle of 44 degrees and a drained cohesion of 200 psf are used for the bearing capacity analysis of the ISFSI and the CTF.

The specified density of the controlled low strength material (CLSM) used to fill beneath the ISFSI pad has also been reduced to 120 pcf to align with the established value for the generic HI-STORM UMAX license, rather than using a conservative value of 150 pcf per the previous HI-STORE submittal. This modification results in a reduction in static bearing pressure for the ISFSI Pad to 3.34 ksf.

Using these revised strength parameters for the Residual Soil, Holtec computed the following allowable bearing capacities and applied bearing pressures on the HI-STORE ISFSI pad and the CTF foundations. In all cases allowable bearing capacity is greater than the applied bearing pressure, indicating bearing capacity factors of safety are adequate.

Structure	**Allowable Static Bearing Capacity (ksf)**		**Bearing Pressure (ksf)**	
	Static	**Seismic**	**Static**	**Seismic**
ISFSI Pad	5.38	8.07	3.34	4.34
CTF	104.02	156.03	4.33	7.05

2) Upon further review, Holtec agrees with the NRC staff that it is preferrable to use consolidation properties from SW1 for settlement analyses since the shape of the plot indicates a soil behavior more in line with classical soil mechanics theory compared to SW2. The shape of the curve of test SW2 appears to show a more severe impact from stress relief due to sampling in the field. In addition, SW1 has a higher initial water content than SW2 (13.7% in SW1 as compared with 8.0% in SW2). In geotechnical literature, compressibility generally relates to water content, with a higher water content correlating with higher compressibility. Therefore, the compressibility properties associated with SW1 should be conservative relative to SW2.

To calculate the maximum past pressure (or preconsolidation stress) for the Chinle Formation, Holtec has performed a Casagrande construction on the consolidation plot of test SW1 following recognized soil mechanics literature. With this method, a preconsolidation stress of approximately 3.1 tons per square foot (tsf) is obtained. Test SW1 was performed at a depth of approximately 74.3 feet (El. 3455.8). At that depth, our calculations predict an existing insitu vertical stress of approximately 4.3 tsf, which would indicate an under-consolidated soil. Given the geology and the information from the field and the lab tests, including the high SPT N-values and relatively low water contents, Holtec believes the measured preconsolidation stress is lower than the actual insitu preconsolidation stress, likely due to stress relief from sampling in the field. Therefore, the revised calculations conservatively assume that the Chinle Formation is normally consolidated (OCR = 1.0), i.e., the maximum past pressure at any depth is equal to the existing insitu vertical effective stress.

The specified density of the controlled low strength material (CLSM) used to fill beneath the ISFSI pad has also been reduced to 120 pcf to align with the established value for the generic HI-STORM UMAX license, rather than using a conservative value of 150 pcf per the previous HI-STORE submittal. This modification results in a reduction in static bearing pressure for the ISFSI Pad to 3.34 ksf.

To make a proper and direct comparison with the 0.2 inch settlement limit presented in Table 2.3.2 of the HI-STORM UMAX FSAR, the long-term settlement for the HI-STORE ISFSI is computed for the same reference pad size evaluated in the generic UMAX license, namely a 5x5 array of VVMs.

An OCR of 1 has been used for the revised settlement calculations for the ISFSI pad and for the CTF foundation. The calculated long-term settlement of the ISFSI pad and CTF foundation are as follows:

Structure	Total Consolidation Settlement in Chinle Formation Center of pad (in)
ISFSI Pad	0.15
CTF	0.11

3 & 4) As noted in the response to RAI 2-32-S, part 2 above, Holtec agrees with the NRC staff that it is preferable to use consolidation properties from SW1 rather than SW2.

Based on GEI's Site Characterization Report, the Chinle Formation is a single unit with the top of the formation between Elevations 3499 and 3502 and the bottom of the formation between Elevations 3322 and 332 (top of Santa Rosa Formation). There is no geologic distinction between "Chinle Formation clay" and "Chinle Formation mudstone." In the boring logs, the distinction between "clay" and "mudstone" is due to the sampling method, i.e., mudstone is called out when the material becomes hard enough to core.

In addition, Holtec compared laboratory index test results from the shallower samples in the Chinle Formation, where Standard Penetration Test (SPT) sampling was performed, with the water content from test SW1 at approximately 74.3 feet below grade. In the literature, compressibility relates to water content and Atterberg limits. Since there are no Atterberg limits tests performed on the Chinle rock cores, Holtec analyzed water content results.

The water content reported at shallower depths in the Chinle are lower than that reported for SW1, which would indicate a lower compressibility. Based on the natural water content values reported in Tables 3 from GEI's Site Characterization Report for the Chinle Formation, at a depth range between 30 and 56.4 feet below grade, Holtec obtained an average water content of 11.7%. The initial water content from SW1 is 13.7% as reported in Table 4 of GEI's Site Characterization Report. The lower water content would correlate with a lower compressibility, and therefore using the SW1 consolidation parameters through the entire Chinle Formation is conservative.

RAI 2-42-S: Justify why a two-layer system, as used in Report No. HI–2188143, Revision 1, "HI-STORE Bearing Capacity and Settlement Calculations," would be appropriate for estimating the bearing capacity and settlement of the storage pads.

Page A9 of Report No. HI–2188143, Revision 1, "HI-STORE Bearing Capacity and Settlement Calculations," states that *"the Chinle Formation mudstone section is considered bedrock. Also, the full depth of the Chinle is considered in the calculation above (175 ft), this is conservative as the mudstone will not settle as much as the clay.*" The response to RAI 2-42 states that "[i]n the latest revision of Report No. HI-2188143, the top CL soil layer is conservatively assumed athroughout the entire 175 ft depth of the Chinle Formation." These statements suggest that the settlement characteristics of the Chinle Formation clay section are different than the Chinle Formation mudrock. Provide the rationale for selecting a two-layer system for estimating the settlement under the storage pads and the Canister Transfer Facility instead of a multilayer system.

This information is necessary to determine compliance with 10 CFR 72.24, 72.103, and 72.122.

Holtec Response:

Based on GEI's Site Characterization Report, the Chinle Formation is a single unit with the top of the formation between Elevations 3499 and 3502 and the bottom of the formation between Elevations 3322 and 3321 (top of Santa Rosa Formation). There is no geologic distinction between "Chinle Formation clay" and "Chinle Formation mudstone". In the boring logs, the distinction between "clay" and "mudstone" is due to the sampling method, i.e., mudstone is called out when the material becomes hard enough to core. According to the boring logs, the Chinle Formation material becomes hard enough to core between Elevations 3434.5 and 3499.6, with an average of 3469.

In response to the questions raised in this RAI, Holtec performed additional settlement calculations for both the ISFSI Pad and the CTF. Given the thickness and properties of the Chinle Formation (see response to RAI 2-32-2), the long-term settlement under the ISFSI Pad and CTF are calculated using a multi-layer system in accordance with the methodology described in Holtec Position Paper DS-338. To calculate the total long term consolidation settlement, the Chinle Formation is divided into four layers between Elevations 3500 and 3469, and two layers between Elevations 3469 and 3321.5.

Only the settlement in the Chinle Formation is considered because the Residual Soil is a granular material which has a low moisture content, is above the water table, and is not saturated. Therefore, the settlement in the Residual Soil will occur immediately upon loading and will not contribute to long term settlement. The rebound due to excavation and reconsolidation back to the initial existing stress in the Chinle Formation is also assumed to occur rapidly. Therefore, the consolidation settlement is calculated from the initial stress (also equal to the maximum past pressure) to the final stress. The revised calculations in Holtec Report HI-2188143 conservatively assume normally consolidated conditions and use the compression index reported in test SW1 to calculate the consolidation settlement (see discussion in response to RAI 2-32-S). The load reduction methodology of 30-degree angle as described in Holtec's Dry Storage Position Paper DS-338, which is incorporated by reference in the HI-STORM UMAX FSAR, is also used.

The specified density of the controlled low strength material (CLSM) used to fill beneath the ISFSI pad has also been reduced to 120 pcf to align with the established value for the generic HI-STORM UMAX license, rather than using a conservative value of 150 pcf per the previous HI-STORE submittal. This modification results in a reduction in static bearing pressure for the ISFSI Pad to 3.34 ksf.

To make a proper and direct comparison with the 0.2 inch settlement limit presented in Table 2.3.2 of the HI-STORM UMAX FSAR, the long-term settlement for the HI-STORE ISFSI is computed for the same reference pad size evaluated in the generic UMAX license, namely a 5x5 array of VVMs.

The final results are summarized in the table below.

Structure	Total Long Term Consolidation Settlement in Chinle Formation Center of pad (in)
ISFSI Pad	0.15
CTF	0.11

References

AASHTO LRFD Bridge Design Specifications, 9th Edition, 2020.

GEI Consultants, Inc. (GEI). HI-STORE CISF Phase 1 Site Characterization Report, Rev 1, Lea County, New Mexico, February 2018.

J. E. Bowles, Foundations Analysis and Design, 5th Edition, McGraw Hill, 1996.

F.H Kulhawy, P.W. Mayne, Manual on Estimating Soil Properties for Foundation Design, Electric Power Research Institute, 1990.

Holtec, Dry Storage Position Paper DS-338, Revision 1, June 23, 2010.

Holtec, HI-STORM UMAX FSAR Rev. 6