March 6, 2003

Joseph D. Ziegler, Acting Director
Office of License Application and Strategy
U.S. Department of Energy
Office of Repository Development
P.O. Box 364629 M/S 523
North Las Vegas, NV 89036-8629

SUBJECT: AGREEMENT UNSATURATED AND SATURATED FLOW UNDER ISOTHERMAL CONDITIONS (USFIC).5.13, STATUS COMPLETE, AND AGREEMENT TOTAL SYSTEM PERFORMANCE ASSESSMENT AND INTEGRATION (TSPAI).2.02, STATUS PARTLY RECEIVED, (COMMENT 3 AND COMMENT 12)

Dear Mr. Ziegler:

In your letter dated July 29, 2002, the U.S. Department of Energy (DOE) responded to two agreements, sending a two-part report entitled "Thermochronological Evolution of Calcite Formation at the Potential Yucca Mountain Repository Site, Nevada: Part 1, Secondary Mineral Paragenesis and Geochemistry"; and "Part 2, Fluid Inclusion Analyses and U-Pb Dating". Also, considered in this review is a three-part 660-page report, funded by the State of Nevada, and published by TRAC Corporation (Szymanski and Harper, 2002; Szymanski et al. 2002; Dublyanski et al., 2002). The TRAC report is relevant because the authors challenge the key conclusions reached in the UNLV report (Wilson and Cline, 2002a, b) regarding the origin and ages of secondary mineral deposits in the unsaturated zone at Yucca Mountain. The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed this information, with respect to Agreements USFIC.5.13 and TSPAI.2.02, Comment 3 and Comment 12. For USFIC.5.13, DOE agreed to provide the documentation of the evaluation of the fluid inclusion studies. For TSPAI.2.02, Comment 3 and Comment 12, DOE agreed to provide the technical basis for the screening arguments for the features, events, and processes (FEPs) items relating to natural geothermal effects and density-driven thermal groundwater flow. These agreements pertain to the hypothesis of heated groundwater reaching repository depth in the Yucca Mountain area due to hydrothermal or seismic activity. The results of the staff's review are enclosed.

The reports cited in the DOE transmittal letter, along with the provided UNLV Report (Wilson and Cline, 2002a, b), represent all of the currently available evaluations resulting from the joint program on fluid inclusion studies of secondary mineral deposits at Yucca Mountain and, therefore, agreement USFIC.5.13 is considered complete.

The TRAC Report does not include any new evidence to provide an adequate basis for the conceptual model of hydrothermal fluids driven by seismic pumping. It does raise, however, some questions about potential biases in the age dating of secondary minerals and the temperature history of Yucca Mountain that will require additional staff review. This additional review will be conducted in conjunction with the staff review of KTI agreement ENFE.2.03, which requests DOE to provide an adequate scenario screening argument for the exclusion of hydrothermal activity from the FEPs considered in performance assessment.

The DOE transmittal letter addressing agreement USFIC.5.13 is also intended to address Comment 3 and Comment 12 of agreement TSPAI.2.02. As indicated by DOE in its letter, the analysis/model report that documents the related FEPs screening arguments will need to be updated to explain how the results of the fluid inclusion studies support the scenario screening arguments discussed in Comment 3 and Comment 12 of TSPAI.2.02. The updated screening arguments will also be reviewed along with DOE's response to agreement ENFE.2.03. The agreement TSPAI.2.02 is considered partly received. If there are any questions regarding this letter, please contact Bill Dam at 301-415-6710 or by e-mail at wld@nrc.gov.

Sincerely,
/RA/

Janet R. Schlueter, Chief
High-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Attachment: NRC Review of DOE Documents Pertaining to Key Technical Issue Agreement USFIC.5.13 and Agreement TSPAI.2.02, Comment 3 and Comment 12

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Letter to J. Ziegler from J. Schlueter dated March 6, 2003

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The DOE transmittal letter addressing agreement USFIC.5.13 is also intended to address Comment 3 and Comment 12 of agreement TSPAI.2.02. As indicated by DOE in its letter, the analysis/model report that documents the related FEPs screening arguments will need to be updated to explain how the results of the fluid inclusion studies support the scenario screening arguments discussed in Comment 3 and Comment 12 of TSPAI.2.02. The updated screening arguments will also be reviewed along with DOE's response to agreement ENFE.2.03. The agreement TSPAI.2.02 is considered partly received. If there are any questions regarding this letter, please contact Bill Dam at 301-415-6710 or by e-mail at wld@nrc.gov.

Sincerely,
/RA/

Janet R. Schlueter, Chief
High-Level Waste Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

Attachment: NRC Review of DOE Documents Pertaining to Key Technical Issue Agreement USFIC.5.13 and Agreement TSPAI.2.02, Comment 3 and Comment 12

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NRC Review of DOE Documents Pertaining to Key Technical Issue Agreements USFIC.5.13 and TSPAI.2.02, Comment 3 and Comment 12

The U.S. Nuclear Regulatory Commission (NRC) goal of issue resolution during this interim pre-licensing period is to assure that the U.S. Department of Energy (DOE) has assembled enough information on a given issue for NRC to accept a licensing application for review. Resolution by the NRC staff during pre-licensing does not prevent anyone from raising any issue for NRC consideration during review of a license application. Just as important, resolution by the NRC staff during pre-licensing does not prejudge what the NRC staff evaluation of that issue will be after its licensing review. Issues are resolved by the NRC staff during pre-licensing when the staff has no further questions or comments about how DOE is addressing an issue. Pertinent new information could raise new questions or comments on a previously resolved issue.

This enclosure pertains to agreement Unsaturated and Saturated Flow under Isothermal Conditions (USFIC).5.13, and agreement Total-System Performance Assessment and Integration (TSPAI).2.02, Comment 3 and Comment 12. These agreements were reached between NRC and DOE during two technical exchange and management meetings.[1, 2] To address these agreements, DOE provided a letter[3] with an attached report by an independent working group at the University of Nevada at Las Vegas (UNLV) that documents investigations of two-phase fluid inclusions found in secondary mineral deposits in the unsaturated zone at Yucca Mountain.

Wording of the Agreements

USFIC.5.13: "Provide the evaluation of the ongoing fluid inclusion studies (for example, UNLV, State of Nevada, and USGS). DOE's consideration of the fluid inclusion studies will be documented in an update to the Saturated Zone Flow and Transport PMR expected to be available in FY 2002, subject to availability of the studies."

TSPAI.2.02: "DOE will provide the technical basis for the screening argument, as summarized in attachment 2, for the highlighted FEPS. The technical basis will be provided in the referenced FEPS AMR and will be provided to the NRC in FY03."

> TSPAI.2.02, Comment 3: "2.2.10.03.00 (Natural geothermal effects). It is stated that natural geothermal effects are included because the current geothermal gradient is addressed in the SZFT model (CRWMS M&O, 2001). However, this discussion does not address the potential for spatial and temporal variation in that gradient, which is part

[1]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Unsaturated and Saturated Flow Under Isothermal Conditions (October 31–November 2, 2000)." Letter (November 17, 2000) to S. Brocoum, DOE.

[2]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Total System Performance Assessment and Integration (August 6–10, 2001)." Letter (August 23) to S. Brocoum, DOE.

[3]Ziegler, J.D. "Transmittal of Information Addressing Key Technical Issue (KTI) Agreement Item Unsaturated and Saturated Flow Under Isothermal Conditions (USFIC) 5.13 and Total-System Performance Assessment and Integration (TSPAI) 2.02, Comments 3 and 12." Letter (July 29, 2002) to J. Schlueter.

of the description of 2.2.10.03.00. Resolution of this issue is necessary to address the issue of changes in the geothermal gradient in 2.2.10.13.00 [Density-driven groundwater flow (thermal)]."

TSPAI.2.02, Comment 12: "2.2.10.13.00 [Density-driven groundwater flow (thermal)]. The saturated zone features, events, and processes analysis and model report (CRWMS M&O, 2001) addresses this item in two parts: repository-induced effects ("excluded," low consequence) and natural geothermal effects ("included"). Exclusion of repository effects on flow based on DOE analyses is accepted. Natural effects are included only to the extent that the 'natural geothermal gradient' is applied in the SZFT model. However, changes in thermal gradients are excluded on the basis of low consequence, with reference to 1.2.06.00.00 (Hydrothermal activity) and 1.2.10.02.00 (Hydrologic response to igneous activity) (CRWMS M&O, 2001). A clear technical basis is not provided under these items that all possible changes in thermal gradients will be localized. The screening argument for 1.2.06.00.00 focuses on geochemical effects (see separate entry), while 1.2.10.02.00 is focused on highly localized igneous intrusions. How these arguments apply to 2.2.10.13.00 is not entirely clear."

NRC Review

Background

Previous studies of the origin of secondary mineral deposits in the unsaturated zone at Yucca Mountain have led to disagreement between different research groups regarding the source of waters that deposited these minerals and, ultimately, the suitability of Yucca Mountain as a potential site for a nuclear waste repository. Researchers from the U.S. Geological Survey (USGS), in support of DOE site characterization of Yucca Mountain, originally postulated that secondary minerals in the unsaturated zone precipitated from downward percolating meteoric waters (e.g., Paces et al., 1996, 1997). Subsequently, researchers for the State of Nevada have interpreted the presence of two-phase fluid inclusions in secondary minerals to be an indication that geothermally heated waters rising from the saturated zone have periodically flooded the unsaturated zone at Yucca Mountain (e.g., Dublyanski et al., 2001).

To address the controversy on the origin of secondary mineral deposits at Yucca Mountain, a joint program was established wherein fluid inclusion studies were conducted independently by researchers from USGS, University of Nevada at Las Vegas (UNLV), and the State of Nevada, using an agreed-upon sampling protocol. The UNLV group studies on the origin and timing of precipitation of secondary minerals have been completed and a two-part report (Wilson and Cline, 2002a, b) was prepared. The UNLV report was forwarded by DOE to NRC staff in response to agreement item USFIC.5.13 and is reviewed herein.

Also considered in this review is a three-part report, funded by the State of Nevada, and published by TRAC Corporation (Szymanski and Harper, 2002; Szymanski et al. 2002; Dublyanski et al., 2002). The 660-page TRAC Report was not submitted by DOE, but it is relevant to this review because the authors challenge the key conclusions reached by the independent UNLV group regarding the origin and ages of secondary mineral deposits in the unsaturated zone at Yucca Mountain.

UNLV Report

The Wilson and Cline (2002a, b) report is focused mainly on two topics: (1) providing independent evaluation of homogenization temperatures for two-phase fluid inclusions found in calcite minerals in the unsaturated zone at Yucca Mountain, and (2) constraining the ages of formation for the two-phase fluid inclusions.

During their investigation, Wilson and Cline (2002a, b) evaluated 155 samples of secondary minerals collected from lithophysal cavities, fractures, and breccias at Yucca Mountain. They report that 90 percent of primary and secondary open space studied in unsaturated tuffs at Yucca Mountain contains no secondary mineral record, and that, where secondary minerals are observed, they predominantly occur at the bases of lithophysal cavities and on the footwalls of angled faults or fractures. Wilson and Cline (2000a, b) conclude that these observations are consistent with formation of secondary minerals in an unsaturated environment. It should be noted, however, that researchers at the Center for Nuclear Waste Regulatory Analyses (CNWRA) have reported finding secondary mineral deposits on both sides of faults (hanging wall and footwall) and on the sides and roofs of lithophysal cavities (e.g., Gray et al., 2000).

Fluid inclusion petrography indicated that 50 percent of samples evaluated by Wilson and Cline (2000b) contained fluid inclusion assemblages with two-phase fluid inclusions. Assemblages of two-phase fluid inclusions also contained single-phase inclusions that did not nucleate a vapor bubble, which is taken to indicate formation at relatively low temperatures. Wilson and Cline (2000b) report that virtually all of the two-phase fluid inclusions were observed to occur in the paragenetically old calcite. Homogenization temperatures for the two-phase fluid inclusions were generally 45–60°C (113-140°F), but higher homogenization temperatures reaching 83°C (181°F) were also estimated for samples from the north portal area, and cooler temperatures of 35–45°C (95-113°F) were estimated for the intensely fractured zone. A potential shortcoming of these analyses is that the Wilson and Cline (2000a, b) analyses appear to be limited to secondary minerals found in fractures and lithophysal cavities. Preliminary results from CNWRA studies (Gray et al., 2000), however, indicate certain types of fault zones have a distinctive secondary calcite mineralization history that is not considered by Wilson and Cline (2002a, b).

Two approaches were used by Wilson and Cline (2002b) to constrain the timing of thermal fluids at Yucca Mountain. First, the age was determined for a type of mineral deposit referred to as magnesium-rich, growth-zoned sparry calcite (MGSC). The MGSC mineral category provides a minimum age for fluids with temperatures high enough to generate two-phase inclusions, owing to the presence of only single-phase liquid-only inclusions within this mineral type. Results indicate that the MGSC began to precipitate across the site between about 2.9 and 1.95 million years, and that MGSC has continued to precipitate to within the last half million years. For the second approach, temporal constraints were determined for samples where datable opal or chalcedony minerals occur in the intermediate or older parts of the mineral crusts, or are spatially related to two-phase fluid inclusions. These opal and chalcedony minerals indicate that two-phase fluid inclusions were estimated to be generally older than 5.32 million years.

Wilson and Cline (2000a, b) conclude that their independent analyses support a conceptual model wherein two-phase fluid inclusions were formed by descending meteoric water that infiltrated a cooling volcanic tuff sequence, became heated, and precipitated secondary

minerals within the unsaturated zone. Although the Wilson and Cline (2002a,b) study provides age constraints for the elevated temperatures indicated by the two-phase fluid inclusions, they do not attempt to explain how the unsaturated zone at Yucca Mountain was able to remain hot for several million years after the last tuffs were erupted over 10 million years ago. Speculation proposed by USGS researchers is that Yucca Mountain remained hot for many millions of years because of slow conductive cooling of magma chambers. Staff have previously commented that this conceptual model of slow cooling is unique and to date lacks adequate support. This concern was discussed at the Technical Exchange and Management Meeting on Evolution of the Near-Field Environment (January 9–12, 2001)[4] and is addressed in Key Technical Issue agreement ENFE.2.03, which requests DOE to document results of the conductive cooling model of the Timber Mountain Caldera magma body.

TRAC Report

Following the publication of the report by Wilson and Cline (2002), a three-part report (Szymanski and Harper, 2002; Szymanski et al. 2002; Dublyanski et al., 2002), funded by the State of Nevada, was published by TRAC Corporation. This 660-page report, hereafter referred to as the TRAC Report, challenges the conclusions reached by the independent UNLV group, and reiterates the hypothesis that upwelling geothermal fluids, driven by seismic pumping, have in the past periodically flooded the entire Yucca Mountain unsaturated zone, and that such flooding is likely to occur again in the future. The TRAC Report, which is still being reviewed by staff, appears to raise some important questions regarding potential biases in age dating of the secondary minerals by researchers at the U.S. Geological Survey. The TRAC report doubts the USGS hypothesis of high heat content in the Yucca Mountain area for five million years by residual volcanogenic effects.

A shortcoming of the TRAC Report is that the TRAC Corporation researchers do not propose a viable mechanism by which seismic pumping in the Yucca Mountain region could produce a saturated zone rise, or mounding, of approximately 400 m (1300 ft), which would be necessary if the two-phase fluid inclusions found near the North Ramp area are indeed indicative of upwelling saturated zone waters. Changes in water table elevations preceding or following large-magnitude earthquakes are a well-documented phenomenon, but, such water level changes are typically small [less than 10 m (33 ft)] and short-lived. No evidence is presented to support TRACs hypothesis that seismicity could cause upwelling of hot water of sufficient distance and volume to reach repository depth.

Evidence provided in the TRAC Report to support the hypothesis of seismic pumping is not applicable to the Yucca Mountain region. For example, Szymanski et al. (2002) cite observations from the 1959 earthquake near Hebgen Lake, Montana, and the 1983 earthquake near Borak Peak, Idaho, as evidence that seismic pumping can mobilize large quantities of water. The references cited by Szymanski et al. (2002) document observations of increased stream flows following these large-magnitude earthquakes, however, the authors do not provide any details about how these events are relevant to the very different hydrogeologic conditions in the Yucca Mountain area. For Hebgen Lake, the only evidence known to the staff of possible

[4]Reamer, C.W. "U.S. Nuclear Regulatory Commission/U.S. Department of Energy Technical Exchange and Management Meeting on Evolution of the Near-Field Environment (January 9–12, 2001)." Letter (January 26, 2001) to S. Brocoum, DOE. Washington, DC: NRC. 2001.

seismic pumping related to the 1959 earthquake is an account that, immediately preceding the event, the well-known Old Faithful Geyser spouted somewhat higher, and for a few minutes longer than usual.[5] The Borah Peak event resulted in the temporary drying of an artesian spring and the temporary flooding of some fields by the formation of new artesian springs. The Borah Peak observations, however, are the result of artesian hydrogeologic conditions, where hydraulic heads in a confined aquifer are higher than the ground surface—a situation that is not applicable to Yucca Mountain. At Yucca Mountain, hydraulic heads in the lower, confined Paleozoic aquifer system are on the order of 50 m (164 ft) higher than in the overlying volcanic aquifer. If an earthquake were to breach the confining layer along a fault zone, temporary mounding of the water table at the fault zone could occur, but the magnitude of such a water table rise would be less than the 50-m (164-ft) hydraulic head difference between the two aquifers.

Carrigan, et al. (1991) discussed the potential for water-table excursions induced by seismic events at Yucca Mountain. They conducted numerical simulations of tectonohydrologic coupling, and estimated that earthquakes typical of the Basin and Range province produce 2 to 3 m excursions of a water table that is 500 m below land surface. They estimated that extraordinary events (analogous to the Dixie Valley-Fairview Peak, Nevada, earthquake or the 1983 Borah Peak earthquake of circa magnitude 7) could cause transient water-table excursions of less than 20 m. NRC (1999) concluded that compared to climate change, seismicity and other mechanisms have the potential to produce water-level changes of relatively small magnitude or duration based on evidence observed to date.

Szymanski et al. (2002, figure 2.3b) also provide an interpretation of water table elevations in wells near Yucca Mountain and suggest the current existence of a water-table mound that is approximately centered on the location of Nye County well EWDP-1S. Water level data from the more recently completed well EWDP-7S, however, are more consistent with the DOE interpretation of water levels in the area and are inconsistent with the Szymanski et al. (2002) hypothesis. Szymanski et al. (2002) support their interpretation of a hydraulic mound near well EWDP-1S by estimating local geothermal gradients from the difference between average ground surface temperature and the water-table temperature, divided by the depth to the water table. They conclude that the geothermal gradient is significantly higher near well EWDP-1S and that this supports their argument of upwelling of geothermally heated water. The approach used by Szymanski et al. (2002), however, is not an acceptable practice for estimating geothermal gradients. The variability of groundwater temperatures near the water table in the Yucca Mountain area tends to be reduced by the predominantly lateral flow of groundwater. An interpretation made by dividing the relatively constant-difference between water table and ground-surface temperatures by the much more variable depth to the water table produces a reflection of the variable topography near Yucca Mountain. The relatively shallow depth to the water table at well EWDP-1S, which is entirely due to topography, causes for the supposedly high geothermal gradient calculated by Szymanski et al. (2002). Water temperature near the water table at well EWDP-1S, postulated to be in the center of a zone of geothermal upwelling, is approximately 28°C (82°F), which is relatively cool compared to the 27–40°C (81-104°F) range of water table temperatures observed in the Yucca Mountain area (e.g., Sass et al.,

[5]Compilation of newspaper articles and individual accounts available at the University of Utah Seismograph Stations (UUSS) Internet site http://www.seis.utah.edu/lqthreat/nehrp_htm/1959hebg/1959he1.shtml, last accessed on January 10, 2003.

1988; see also temperature data available on Nye County Internet site[6]). Szymanski et al. (2002) erroneously report a water temperature of 54.3°C (129.7°F) near the water table in well EWDP-12PA, whereas data at the Nye County Internet site indicate a much cooler temperature of about 32°C (90°F).

Staff Comments and Conclusions:

Agreement USFIC.5.13 requested DOE to provide available evaluations of the fluid inclusion studies that have been conducted on secondary mineral deposits found in the unsaturated zone at Yucca Mountain. The independent UNLV Report provided by DOE provides the most recent evaluation of fluid inclusion studies that DOE will use to support their argument that secondary minerals deposits in the Yucca Mountain unsaturated zone precipitated from downward percolating meteoric waters. The DOE transmittal letter also cites the TRAC Report and two U.S. Geological Survey publications that also present results from the joint research program on fluid inclusion studies. The reports cited in the DOE transmittal letter along with the provided UNLV Report, represent all of the currently available evaluations resulting from the joint program on fluid inclusion studies of secondary mineral deposits at Yucca Mountain. Therefore, agreement USFIC.5.13 is considered complete.

The TRAC Report does not include any new evidence to provide an adequate basis for the conceptual model of hydrothermal fluids driven by seismic pumping. It does raise, however, some questions about potential biases in the age dating of secondary minerals and the temperature history of Yucca Mountain that will require additional staff review. These issues, as well as the findings from the CNWRA studies (Gray et al., 2000), will be conducted in conjunction with the staff review of Key Technical Issue agreement ENFE.2.03, which requests DOE to provide an adequate scenario screening argument for the exclusion of hydrothermal activity from the FEPs considered in performance assessment.

The DOE transmittal letter addressing agreement USFIC.5.13 is also intended to address Comment 3 and Comment 12 of agreement TSPAI.2.02. As indicated by DOE in its letter, the analysis/model report that documents the related FEPs screening arguments will need to be updated to explain how the results of the fluid inclusion studies support the scenario screening arguments discussed in Comment 3 and Comment 12 of TSPAI.2.02.

Status of Agreements: USFIC.5.13 is complete. TSPAI.2.02 is partly received pending revision of relevant FEPs screening arguments.

[6]Data available at http://www.nyecounty.com, last accessed January 10, 2003.

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