U.S. NUCLEAR REGULATORY COMMISSION STAFF REVIEW OF THE DOCUMENTATION PROVIDED BY TENNESSEE VALLEY AUTHORITY FOR THE SEQUOYAH NUCLEAR PLANT UNITS 1 AND 2 CONCERNING RESOLUTION OF GENERIC LETTER 2004-02 *POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN-BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS*

1.0 INTRODUCTION

A fundamental function of the emergency core cooling system (ECCS) is to recirculate water that has collected at the bottom of the containment through the reactor core following a break in the reactor coolant system (RCS) piping to ensure long-term removal of decay heat from the reactor fuel. Leaks from the RCS, hypothetical scenarios known as loss-of-coolant accidents (LOCAs), are part of every plant's design-basis. Hence, nuclear plants are designed and licensed with the expectation that they are able to remove reactor decay heat following a LOCA to prevent core damage. Long-term cooling following a LOCA is a basic safety function for nuclear reactors. The recirculation sump provides a water source to the ECCS in pressurized-water reactors (PWRs) once the primary water source has been depleted.

If a LOCA occurs, piping thermal insulation and other materials may be dislodged by the two-phase coolant jet emanating from the broken RCS pipe. This debris may transport, via flows coming from the RCS break or from the containment spray system (CSS), to the pool of water that collects at the bottom of containment following a LOCA. Once transported to the sump pool, the debris could be drawn towards the ECCS sump strainers, which are designed to prevent debris from entering the ECCS and the reactor core. If this debris were to clog the strainers and prevent coolant from entering the reactor core, containment cooling could be lost and result in core damage and containment failure.

It is also possible that some debris would bypass the sump strainer and lodge in the reactor core. This could result in reduced core cooling and potential core damage. If the ECCS strainer were to remain functional, even with core cooling reduced, containment cooling would be maintained and the containment function would not be adversely affected.

Findings from research and industry operating experience raised questions concerning the adequacy of PWR sump designs. Research findings demonstrated that, compared to other LOCAs, the amount of debris generated by a high-energy line break (HELB) could be greater. The debris from a HELB could also be finer (and thus more easily transportable) and could be comprised of certain combinations of debris (i.e., fibrous material plus particulate material) that could result in a substantially greater flow restriction than an equivalent amount of either type of debris alone. These research findings prompted the U.S. Nuclear Regulatory Commission (NRC) to open Generic Safety Issue (GSI) - 191, "Assessment of Debris Accumulation on PWR Sump Performance," in 1996. This resulted in new research for PWRs in the late 1990s. GSI-191 focuses on reasonable assurance that the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.46(b)(5) are met. This rule, which is deterministic, requires maintaining long-term core cooling after initiation of the ECCS. The objective of GSI-191 is to ensure that postaccident debris blockage will not impede or prevent the operation of the ECCS and CSS in recirculation mode at PWRs during LOCAs or other HELB accidents for which sump recirculation is required. The NRC completed its review of GSI-191 in 2002 and documented the results in a parametric study that concluded that sump clogging at PWRs was a credible concern.

GSI-191 concluded that debris clogging of sump strainers could lead to recirculation system ineffectiveness as a result of a loss of net positive suction head (NPSH) for the ECCS and CSS recirculation pumps. Resolution of GSI-191 involves two distinct but related safety concerns: (1) potential clogging of the sump strainers that results in ECCS and/or CSS pump failure; and (2) potential clogging of flow channels within the reactor vessel because of debris bypass of the sump strainer (in-vessel effects). Clogging at either the strainer or in-vessel channels can result in loss of the long-term cooling safety function.

After completing the technical assessment of GSI-191, the NRC issued Bulletin 03-01, "Potential Impact of Debris Blockage on Emergency Sump Recirculation at Pressurized-Water Reactors" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML031600259), on June 9, 2003. The Office of Nuclear Reactor Regulation (NRR) requested and obtained the review and endorsement of the bulletin from the Committee to Review Generic Requirements (CRGR) (ADAMS Accession No. ML031210035). As a result of the emergent issues discussed in Bulletin 03-01, the NRC staff requested an expedited response from PWR licensees on the status of their compliance of regulatory requirements concerning the ECCS and CSS recirculation functions based on a mechanistic analysis. The NRC staff asked licensees, who chose not to confirm regulatory compliance, to describe any interim compensatory measures that they had implemented or will implement to reduce risk until the analysis could be completed. All PWR licensees responded to Bulletin 03-01. The NRC staff reviewed all licensees' Bulletin 03-01 responses and found them acceptable.

In developing Bulletin 03-01, the NRC staff recognized that it might be necessary for licensees to undertake complex evaluations to determine whether regulatory compliance exists in light of the concerns identified in the bulletin and that the methodology needed to perform these evaluations was not currently available. As a result, that information was not requested in Bulletin 03-01, but licensees were informed that the NRC staff was preparing a generic letter (GL) that would request this information. GL 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design-basis Accidents at Pressurized-Water Reactors," dated September 13, 2004 (ADAMS Accession No. ML042360586), was the follow-on information request referenced in Bulletin 03-01. This document set the expectations for resolution of PWR sump performance issues identified in GSI-191, to ensure the reliability of the ECCS and CSS at PWRs. NRR requested and obtained the review and endorsement of the GL from the CRGR (ADAMS Accession No. ML040840034).

The GL 2004-02 requested that addressees perform an evaluation of the ECCS and CSS recirculation functions in light of the information provided in the letter and, if appropriate, take additional actions to ensure system function. Additionally, addressees are requested to submit the information specified in this letter to the NRC. This request is based on the identified potential susceptibility of PWR recirculation sump screens to debris blockage during design-basis accidents requiring recirculation operation of ECCS or CSS and on the potential for additional adverse effects due to debris blockage of flow paths necessary for ECCS and CSS recirculation and containment drainage. The GL 2004-02 required addressees to provide the NRC a written response in accordance with 10 CFR 50.54(f).

By letter dated May 28, 2004 (ADAMS Accession No. ML041550279), the Nuclear Energy Institute (NEI) submitted a report describing a methodology for use by PWRs in the evaluation of containment sump performance. NEI requested that the NRC review the methodology. The methodology was intended to allow licensees to address and resolve GSI-191 issues in an expeditious manner through a process that starts with a conservative baseline evaluation. The baseline evaluation serves to guide the analyst and provide a method for quick identification and evaluation of design features and processes that significantly affect the potential for adverse containment sump blockage for a given plant design. The baseline evaluation also facilitates the evaluation of potential modifications that can enhance the capability of the design to address sump debris blockage concerns and uncertainties and supports resolution of GSI-191. The report offers additional guidance that can be used to modify the conservative baseline evaluation results through revision to analytical methods or through modification to the plant design or operation.

By letter dated December 6, 2004 (ADAMS Package Accession No. ML043280641), the NRC issued an evaluation of the NEI methodology. The NRC staff concluded that the methodology, as approved in accordance with the NRC staff safety evaluation (SE), provides an acceptable overall guidance methodology for the plant-specific evaluation of the ECCS or CSS sump performance following postulated design-basis accidents.

In response to the NRC staff SE conclusions on NEI 04-07, the Pressurized Water Reactor Owners Group (PWROG) sponsored the development of the following Westinghouse Commercial Atomic Power (WCAP) Topical Reports (TRs):

- TR-WCAP-16406-P-A, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Revision 1 (not publicly available), to address the effects of debris on piping systems and components.

- TR-WCAP-16530-NP-A, "Evaluation of Postaccident Chemical Effects in Containment Sump Fluids to Support GSI-191," issued March 2008 (ADAMS Accession No. ML081150379), to provide a consistent approach for plants to evaluate the chemical effects that may occur postaccident in containment sump fluids.

- TR-WCAP-16793-NP-A, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," Revision 2 (ADAMS Accession No. ML13239A114), to address the effects of debris on the reactor core.

The NRC staff reviewed the TRs and found them acceptable to use (as qualified by the limitations and conditions stated in the respective SEs). A more detailed evaluation of how the TRs were used by the licensee is contained in the evaluations below.

After the NRC staff evaluation of licensee responses to GL 2004-02, the NRC staff found that there was a misunderstanding between the industry and the NRC on the level of detail necessary to respond to GL 2004-02. The NRC staff in concert with stakeholders developed a content guide for responding to requests for additional information (RAIs) concerning GL 2004-02. By letter dated August 15, 2007 (ADAMS Accession No. ML071060091), the NRC issued the content guide describing the necessary information to be submitted to allow the NRC staff to verify that each licensee's analyses, testing, and corrective actions associated with

GL 2004-02 are adequate to demonstrate that the ECCS and CSS will perform their intended function following any design-basis accident. By letter dated November 21, 2007 (ADAMS Accession No. ML073110389), the NRC issued a revised content guide.

The content guide described the following information needed to be submitted to the NRC:

- Corrective Actions for GL 2004-02
- Break Selection
- Debris Generation/Zone of Influence (ZOI) (Excluding Coatings)
- Debris Characteristics
- Latent Debris
- Debris Transport
- Head Loss and Vortexing
- Net Positive Suction Head
- Coatings Evaluation
- Debris Source Term
- Screen Modification Package
- Sump Structural Analysis
- Upstream Effects
- Downstream Effects – Components and Systems
- Downstream Effects – Fuel and Vessel
- Chemical Effects
- Licensing Basis

Resolution of GSI-191 has been more difficult than anticipated. Based on the interactions with stakeholders and the results of the industry testing, the NRC staff in 2012 developed three options that will be effective ways to resolve GSI-191. These options were documented and proposed to the Commission in SECY-12-0093, "Closure Options for Generic Safety Issue - 191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance," dated July 9, 2012 (ADAMS Accession No. ML121310648). The options are summarized as follows:

- Option 1 would require licensees to demonstrate compliance with 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors," through approved models and test methods. These will be low fiber plants with less than 15 grams of fiber per fuel assembly

- Option 2 requires implementation of additional mitigating measures and allows additional time for licensees to resolve issues through further industry testing or use of a risk informed approach.

    - Option 2 Deterministic: Industry to perform more testing and analysis and submit TR-WCAP for NRC review and approval (in-vessel only).

    - Option 2 Risk Informed: Use the South Texas Project pilot approach currently under review with NRR staff.

- Option 3 involves separating the regulatory treatment of the sump strainer and in-vessel effects.

The options allowed industry alternative approaches for resolving GSI-191. The options are innovative and creative, as well as risk informed and safety conscious. The Commission issued a Staff Requirement Memorandum on December 14, 2012 (ADAMS Accession No. ML12349A378), approving all three options for closure of GSI-191.

By letter dated May 16, 2013 (ADAMS Accession No. ML13142A198), Tennessee Valley Authority (TVA, the licensee) stated that they will pursue Option 1 for the closure of GSI-191 and GL 2004-02 for the Sequoyah Nuclear Plant Units 1 and 2 (Sequoyah 1 and 2).

The following is a list of documentation provided by the licensee in response to GL 2004-02:

RESPONSES TO GL 2004-02		
DOCUMENT DATE	ACCESSION NUMBER	
March 7, 2005	ML050700255	
July 21, 2005	ML052080065	
September 1, 2005	ML052500298	
September 30, 2005	ML052850352	
1st NRC RAI February 10, 2006 Accession No. ML060370480		
Licensee Responses to RAIs		
April 11, 2006	ML061020313	
December 21, 2006	ML063620411	Supplemental Information
November 28, 2007	ML073370317	Supplemental Information
February 29, 2008	ML080640205	Supplemental Information
2nd NRC RAI November 25, 2008 Accession No. ML083230823		
Licensee Response to RAIs		
February 23, 2009	ML090540857	
April 1, 2010	ML100960020	Supplemental Information
3rd NRC RAIs October 14, 2009 Accession No. ML092780335		
Licensee's Response to RAIs		
June 2, 2011	ML11158A045	
June 27, 2014	ML14182A576	Supplemental Information

The NRC staff reviewed the information provided by the licensee in response to GL 2004-02 and all RAIs. The following is a summary of the NRC staff review.

2.0 GENERAL DESCRIPTION OF CORRECTIVE ACTIONS FOR THE RESOLUTION OF GL-2004-02

The following is a list of corrective actions taken by the licensee at Sequoyah 1 and 2 in support of the resolution of GL 2004-02:

- Evaluation using the guidance of NEI 04-07. COMPLETE.

- Downstream effects evaluation using the TR-WCAP-16406-P-A, Revision 1 methodology. Containment walkdowns using the guidance of NEI 02-01, "Condition Assessment Guidelines: Debris Sources Inside PWR Containments," April 19, 2002 (ADAMS Accession No. ML021490212). COMPLETE.

- The modification process and maintenance process have been enhanced relative to GL 2004-02 controls to insure operability of the containment sumps. COMPLETE.

- Installation of a new ECCS sump strainer in Units 1 and 2 (≈ 1,609 square feet (ft^2)). COMPLETE.

- ECCS sump strainer performance for Sequoyah was confirmed by performing a prototype chemical precipitates head loss test. COMPLETE.

Based on the information provided by the licensee, the NRC staff considers this item closed for GL 2004-02.

3.0 BREAK SELECTION

The objective of the break selection process is to identify the break size and location that present the greatest challenge to postaccident sump performance. The term ZOI used in this section refers to the spherical zone representing the volume of space affected by the ruptured piping.

INITIAL NRC STAFF REVIEW:

The initial NRC staff review is based on documentation provided by the licensee through February 29, 2008.

The licensee used the NEI 04-07 guidance report (GR) and the associated NRC staff SE (GR/SE) guidance for break selection, with the exception that the break was not moved incrementally along the pipe to determine the location that resulted in the maximum debris generation. The process was simplified to pick break locations based on ZOIs. The response stated that the simplification did not reduce the debris amounts for the worst-case conditions. The ZOI used for qualified coatings was larger at 10 diameters (D) than the 5D ZOI used by more recent analyses. The 10D ZOI results in a volume 8 times larger than a 5D ZOI, greatly increasing the amount of coatings assumed damaged by the jet. The licensee assumed that all insulating material within the compartment in which the break occurred was destroyed. Because the ZOIs used by the licensee were large enough to result in the destruction of all insulation material within the compartment in which the break occurred and the coatings ZOI was large, the break selection process is conservative and acceptable.

In addition to the above, secondary breaks were not considered in the break selection process because they do not result in recirculation for any design-basis high energy line break events. The licensee assumed that all insulating material within the compartment in which the break occurred was destroyed.

FINAL NRC STAFF REVIEW:

The initial NRC staff review found the break selection area to be addressed adequately. There was no RAI. There were no changes made in this area.

FINAL NRC STAFF CONCLUSION:

For this review area, the licensee has provided sufficient information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically.

The NRC staff concludes that the break selection evaluation for Sequoyah 1 and 2 is acceptable. Based on the information provided by the licensee, the NRC staff considers this area closed for GL 2004-02.

4.0 DEBRIS GENERATION/ZONE OF INFLUENCE (EXCLUDING COATINGS)

The objective of the debris generation/ZOI evaluation is to determine the limiting amounts and combinations of debris that can occur from the postulated breaks in the reactor coolant system.

INITIAL NRC STAFF REVIEW:

The initial NRC staff review is based on documentation provided by the licensee through February 29, 2008.

The Debris Generation/ZOI evaluation conducted by the licensee was performed adequately and provided the information specified in the content guide. The licensee used the NEI 04-07 GR Section 4.2.2.1.1 ZOI refinement of debris-specific spherical ZOIs. The licensee also used the GR/SE default ZOI of 28.6D for reflective metallic insulation (RMI) with standard bands. With the 28.6D ZOI, essentially all insulation in each coolant loop vault or zone is affected regardless of where the break occurs in the loop piping. RMI is the only insulation within the ZOI. The licensee performed containment walkdowns and estimated a maximum total surface area for all signs, placards, tags, tape, and similar miscellaneous materials to be 850 ft^2. All of this debris is assumed to transport to the sump. Consistent with the GR/SE Section 3.5.2.2.2, a 75 percent packing ratio is applied to result in a 637.5 ft^2 sump strainer surface area blockage. The licensee used the GR/SE default ZOI value of 10.0D for qualified coatings (epoxy and epoxy-phenolic paint) rather than a lesser value based on more specific experimental data. The 10D ZOI for coatings is conservative.

FINAL NRC STAFF REVIEW:

The final review is based on the licensee's RAI responses and supplemental information through June 27, 2014.

Sequoyah 1 and 2 are considered to be clean because they have no fibrous or problematic insulation installed within any postulated ZOI. The plant has installed RMI exclusively in areas where debris may be generated. This makes the plant less problematic from a sump strainer blockage perspective.

The initial NRC staff review found the area to be addressed adequately. There were no changes to the licensee's debris generation evaluation. Therefore, the area has been addressed acceptably.

FINAL NRC STAFF CONCLUSION:

For the debris generation/ZOI review area, the licensee provided information such that the NRC staff has reasonable assurance that the subject review area has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the debris generation evaluation for Sequoyah 1 and 2 is acceptable. The NRC staff considers this item closed for GL 2004-02.

5.0 DEBRIS CHARACTERISTICS

The objective of the debris characteristics determination process is to establish a conservative debris characteristics profile for use in determining the transportability of debris and its contribution to strainer head loss.

INITIAL NRC STAFF REVIEW:

The initial NRC staff review is based on documentation provided by the licensee through February 29, 2008.

The licensee based their debris characteristics on the GR/SE, and manufacturer data. In addition to the debris size distributions, the licensee provided a table of applicable material densities. There is one potential error in this density table where the table quotes the densities applicable to the inorganic zinc paint fines of 223 pound mass per cubic foot (lbm/ft^3) for the material density and 145 lbm/ft^3 for the particulate density, whereas these two densities are identical for the other coatings particulates. Although, these densities are incorrect, the error would make no difference to the resolution outcome. Because the head losses were experimentally determined the densities are not important to the calculation of head loss. The licensee also assumed that all of the debris transports to the strainer so that any error in density will not reduce the amount of transport to the strainer.

The size distribution for the different type of debris applicable to the Sequoyah 1 and 2 containment buildings are as follows:

RMI: Section 3.4.3.3.2 of NEI 04-07 recommends using a size distribution of 75 percent small pieces and 25 percent large pieces, where small pieces are defined as anything less than 4 inches (in.). This recommendation was used to size the Sequoyah 1 and 2 RMI debris.

Coatings: Essentially all steel surfaces at Sequoyah are coated with Carbon-zinc TIM 11 (an inorganic zinc primer) and were left un-top-coated. All qualified coatings outside the coatings ZOI will remain intact. Coatings inside the ZOI are assumed to fail as 10 micrometer (μm) particles per the GR/SE guidance.

For latent debris the licensee assumed that the representative size and density of dirt/dust particulate was 17.3 μm and 169 lbm/ft^3, respectively, based on Section 3.5.2.3 of the NRC SE for NEI 04-07. For latent fiber the bulk density was assumed to be 2.4 lbm/ft^3, and the material (individual fiber) density of latent fiber was assumed to be 94 lbm/ft^3 based on Section 3.5.2.3 of the GR/SE for NEI 04-07. The GR/SE does not give a characteristic latent fiber diameter, but it does indicate that it is appropriate to assume the same diameter as commercial fiberglass (7 μm for Nukon® per NUREG/CR-6224, "Parametric Study of the Potential for BWR [Boiling-Water Reactor] ECCS Strainer Blockage Due to LOCA Generated Debris" ADAMS Accession No. ML083290498). This value was used for the Sequoyah analysis.

The debris characterization assumptions used in the Sequoyah debris generation analysis are consistent with NEI 04-07 as modified by the NRC SE for NEI 04-07. No deviation from the guidance documents was required, as stated by the licensee. Coatings are reviewed in more detail in the coatings section.

<u>FINAL NRC STAFF REVIEW</u>:

No changes were made in the area of debris characteristics. Therefore the conclusions of the first round review remain valid and the licensee has addressed the area of debris characteristics adequately. The second round review also noted the errors in the material properties reported by the licensee. However, it was determined, similar to the first round review, that these errors were not consequential to the licensee's overall evaluation. Therefore the area has been adequately addressed.

<u>FINAL NRC STAFF CONCLUSION</u>:

For the debris characteristics area, the licensee has provided information such that the NRC staff has reasonable assurance that it has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the debris characteristics evaluation for Sequoyah 1 and 2 is acceptable. The NRC staff considers this area closed for GL 2004-02.

6.0 LATENT DEBRIS

The objective of the latent debris evaluation process is to provide a reasonable approximation of the amount and types of latent debris (e.g., miscellaneous fiber, dust, dirt) existing within the containment and its potential impact on sump screen head loss.

<u>INITIAL NRC STAFF REVIEW</u>:

The NRC staff review is based on documentation provided by the licensee through February 29, 2008.

Latent Debris Fiber and Particulate:

A quantitative latent debris walkdown was performed for Unit 2. A walkdown was not performed for Unit 1; however, the licensee considered the walkdown information for Unit 2 applicable to Unit 1 based on the following: 1) the same personnel and procedures are used for housekeeping on both containments; and 2) a complete and comprehensive cleaning of the entire containment was performed following the recent completion of the steam generator replacement activities on Sequoyah Unit 1. Based on the comprehensive cleaning of Unit 1, the Sequoyah Unit 2 walkdown was chosen as the bounding case for establishing the latent debris inventory for input to the analysis and licensing basis for the new sump strainer design. Tags, tapes, and labels are assumed to fail regardless of break size and location.

The latent debris source terms were taken from NEI 04-07. The actual values from the Unit 2 walkdown were approximately 50 pounds (lb) of particulate debris and less than ten lb small individual fibers. The value used in the analysis for fiber is many orders of magnitude higher than was actually found. There was not sufficient fiber found to form any type of fiber bed on the sump screens.

The results of the Sequoyah Unit 2 survey were extrapolated to apply to Sequoyah Unit 1 based on the observations of the survey staff and the common containment cleanliness practices applied to both units.

The assumptions concerning latent debris in the Sequoyah containment building involved 1) latent debris types, 2) latent debris physical characteristics, and 3) total quantities of latent debris. Consistent with the guidance provided in the GR/SE for NEI 04-07, the latent debris characteristics were assumed to be as follows:

Fiber contributes 15 percent of the mass of the total latent debris inventory with particulate contributing the remaining 85 percent.

Latent fiber material has an average density of 94 lbm/ft^3

Latent particulate material has a nominal density of 169 lbm/ft^3

Latent fiber material has an as-manufactured density (dry bed bulk density) of 2.4 lbm/ft^3

Latent fiber has the same diameter as commercial fiberglass (7 μm for Nukon® per NUREG/CR-6224).

Based on Section 3.5.2.2 of NEI 04-07, the maximum quantity of latent debris inside containment was assumed to be 200 lb. Of the 200 lb, 170 lb was assumed to be dirt/dust and the remaining 30 lb was assumed to be fiber.

Sacrificial Screen Area:

A sacrificial surface area of 637.5 ft^2 has been established for latent debris in the form of signs, placards, tags, tape and similar miscellaneous materials as discussed in Section 4 of this document.

FINAL NRC STAFF REVIEW

The final NRC staff review is based on information received through June 27, 2014.

The licensee revised its assumption for latent debris in containment. The licensee stated that they are a clean plant in accordance with the NRC's clean plant criteria, NRC Letter dated May 2, 2012 (ADAMS Accession No. ML120730181), and that their assumed latent fiber load is 14 lb for in-vessel calculations. For strainer calculations the licensee assumes 15 lb of latent fiber because this value meets both the clean plant criteria and is the amount of debris included in the licensee's final strainer test program. The licensee plans to increase the design-basis load from 14 lb to 15 lb if a higher fiber limit is justified by ongoing industry work for in-vessel effects (see further discussion in the Head Loss and Vortexing section). The licensee's assumed latent debris load is conservative compared to the amount of latent debris found in containment during sampling. Therefore the assumed amount is acceptable.

In addition, the licensee performed transport testing on the types of tags and labels that are installed within the containments at Sequoyah 1 and 2 and determined that they would not transport to the strainer. Therefore, the 637.5 ft^2 of sacrificial area is reduced to 200 ft^2. The licensee maintained 200 ft^2 of sacrificial area to provide conservatism for head loss testing and evaluations. The NRC staff considers testing of materials to show whether they will transport within the post-LOCA pool to be an acceptable methodology. Therefore the reduction in the amount of miscellaneous debris reaching the strainer and its associated sacrificial area is acceptable.

NRC FINAL STAFF CONCLUSION:

For this review area, the licensee has provided information such that there is reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. The NRC staff considers the latent debris area to be adequately evaluated by the licensee. Therefore, the NRC staff considers this item closed for GL 2004-02.

7.0 DEBRIS TRANSPORT

The objective of the debris transport evaluation process is to estimate the fraction of debris that would be transported from debris sources within containment to the sump suction strainers.

INITIAL NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through February 29, 2008.

The licensee provided the information requested in the content guide. No significant deficiencies or uncertainties were identified in licensee's debris transport analysis based upon the NRC staff's review. With the exception of RMI, for which a reasonable debris transport fraction of 51 percent was calculated, full transport to the strainers was assumed for debris at Sequoyah 1 and 2.

The licensee stated that the transport calculation followed guidance from NEI 04-07 and the NRC staff's SE. The licensee stated that the four major debris transport modes were considered: blowdown, washdown, pool fill-up, and recirculation. The licensee's evaluation of each phase is discussed briefly below.

Blowdown:

The licensee stated that fines were assumed to be blown upward into the ice condenser. RMI was assumed to be blown to the containment floor.

Washdown:

The licensee stated that all debris blown upward would be trapped by the ice baskets and subsequently washed back down to the lower containment with flows from the melting ice.

Pool Fill-Up:

No debris was assumed to transport to hold-up volumes in the incore tunnel or reactor cavity, since communication points with these volumes are above the containment minimum water level.

Recirculation:

The licensee performed a computational fluid dynamics (CFD) analysis of the containment pool to determine the flow velocities and turbulence in the containment pool. Flow-3D was the CFD code used.

Transport metrics were not specified for the various debris types in containment. However, the staff expects that 51-percent transport for RMI is reasonable, and notes that significant head loss is not typically expected for this debris type, even if it can climb up and adhere to the strainers. Full transport was assumed for the remainder of the debris, which was considered fines (some of the failed coatings could possibly be chips with full transport — see coating section for additional discussion).

Complete transport was assumed for fine debris.

No transport to inactive containment pool volumes was modeled.

Fifty-one percent transport for RMI is an overestimate of the actual transport that would occur in the plant, but does not significantly affect the overall conservatism of the evaluation due to how the head loss testing was run and overall minor head loss implications associated with RMI.

Although the licensee analytically reported 100-percent transport for all types of debris other than RMI and a 51-percent transport percentage for RMI, the head loss testing for Sequoyah heavily credited near field settling in the test flume. The licensee stated that near-field credit was not taken; however, this licensee apparently defines near-field settling differently than the NRC staff. Concerns with the suspected nonprototypical handling of the transport credit taken associated with the Sequoyah head loss testing will be addressed in the head loss section of this summary.

INITIAL NRC STAFF CONCLUSION:

The licensee used conservative transport metrics. Therefore the transport evaluation was conducted conservatively and acceptably.

FINAL NRC STAFF REVIEW:

The final NRC staff review of the transport area is based on the licensee's RAI responses and supplemental information through June 27, 2014.

The final review found that the initial review remained valid and that the area had been addressed adequately. The transport review noted that some aspects of transport in the head loss testing were not adequately addressed in the licensee's initial submittal or their response to RAIs. These issues are covered in the head loss and vortexing review. Therefore, the transport area has been adequately addressed. Based on the licensee's RAI responses and supplemental information through June 27, 2014.

FINAL NRC STAFF CONCLUSION:

For the transport area, the licensee has provided adequate information so that the NRC staff has reasonable assurance that the area was addressed conservatively. Therefore, the NRC staff considers this area closed for GL 2004-02.

8.0 HEAD LOSS AND VORTEXING

The objectives of the head loss and vortexing evaluations are to calculate head loss across the sump strainer and to evaluate the susceptibility of the strainer to vortex formation.

INITIAL NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through February 29, 2008.

The licensee's approach to reducing strainer head loss was to limit the amount of fibrous debris available to form a bed on the strainer. The licensee's test program was run using test methods that have not been shown to be prototypical or conservative. The Sequoyah testing was similar to that performed for Watts Bar Nuclear Plant Unit 1. The Watts Bar audit report dated February 7, 2007 (ADAMS Accession No. ML070380083), found the test methods to result in potentially nonconservative head loss. The problems with the methodology require additional information to determine if the test program resulted in realistic or conservative head loss values. The issues relate to debris preparation, debris addition, flume flow velocities, and the practice of adding debris prior to starting the test recirculation pump.

In addition to the above, during a small break LOCA (SBLOCA), the strainer is not fully submerged. The information provided regarding the operation of the strainer under partially submerged conditions is not adequate to show that the strainer will perform adequately.

The licensee reports that containment only contains 24 lb of latent fibrous debris. Strainer testing was completed based on a 200 lb latent debris term. The licensee stated that the test quantities of fiber are more than an order of magnitude greater than the actual amount of fiber in the plant. In addition, the licensee states that there are no fibrous debris sources installed within any ZOI. If the licensee's quantification of latent fibrous debris is accurate, it may allow the licensee to show that head loss testing is not necessary.

The following issues with the licensee's test program and evaluation were identified during the initial NRC staff review:

1. Because of the marginal amount of fibrous debris available to create a bed, the preparation of the debris, the debris addition, and the flow conditions in the test flume are critical. Based on observations from the Watts Bar testing, the preparation of the fibrous debris was likely a generic mixture of fiber sizes rather than the fine fiber that would actually reach the strainer. The introduction of debris prior to starting the pump and the concentration of debris in the test flume likely resulted in nonprototypical agglomeration and settling of debris. Therefore, the results of the head loss testing performed by the licensee are likely nonconservative with respect to the assumed debris loading. The testing protocol used was determined to be unacceptable.

2. The clean strainer head loss calculation is based on vendor data from prototype testing of BWR strainers. The application of the prototype correlation to PWR strainers has not been accepted by the NRC staff. The strainer vendor has committed to providing information supporting the applicability of the correlation to PWR strainers. However, the staff has not been provided with the information as of this time. Other PWR installations from this vendor have recently found their clean strainer head loss calculations to be in error by several ft. A clear basis for the clean strainer head loss calculation should be provided. The clean strainer head loss issue alone may result in negative NPSH margin.

3. Although potential vortexing was addressed by the licensee, the performance of the strainer under partially submerged conditions was not addressed. During a SBLOCA, the strainer area available is reduced because the strainer is not completely covered with water. In addition, Regulatory Guide 1.82 provides considerations for the operation of partially submerged strainers. The issue of potential strainer failure due to partial submergence/venting was not addressed by the licensee. In addition, information regarding the reduction in strainer surface area due to partial submergence was not provided.

4. The licensee stated that no containment accident pressure was credited in the determination that flashing would not occur across the strainer surface. The submittal also states that the strainer is not fully submerged during a SBLOCA. Because strainer submergence is zero, and flashing is considered to occur when submergence is less than head loss, some evaluation of flashing must be conducted. The Performance Contracting Inc. (PCI) strainers have considerable clean strainer head loss.

<u>Initial Round RAIs and NRC Staff Evaluation:</u>

The following RAI numbers correspond to the RAI numbering from the NRC RAIs dated November 25, 2008.

Summary of RAIs 1A through 1G:

RAI 1 was split into several parts. Each part addresses one aspect of the strainer testing methodology and asks for information as to whether the methods used were conservative or prototypical when compared to the plant. A summary of the licensee's response and staff evaluation of each response are provided for each of the sub-issues.

1. Provide the test protocol used for head loss testing and a justification that shows the following aspects of the testing were conservative or prototypical:

RAI 1A Summary:

Addition of debris to the test flume prior to the starting of the recirculation pump.

RAI 1A Licensee Response:

In response to RAI 1A, the licensee described the test methodology in greater detail than in the original supplemental response. The licensee stated that the debris (mixed with water) was added to the flume with the water level at about 6 in. The debris was added 3 to 15 ft from the strainer, which was intended to minimize agglomeration and maximize transport. RMI was added first to prevent it from preventing the transport of other debris. The flume was then filled using overhead nozzles intended to keep the debris mixture in suspension. The debris was also manually stirred prior to starting the recirculation pump.

RAI 1A NRC Staff Evaluation:

Although the licensee provided measures that were taken to ensure that debris was properly added to the test, there is no justification as to how these actions ensured that the testing was valid. The procedure described does not follow any of the staff accepted test methodologies. The NRC staff expressed concern with this aspect of the procedure in trip reports and found it likely to result in nonconservative results. This concern was based on observation of the testing for other plants using a similar procedure. Most plants that used this test procedure have retested due to the nonconservatism resulting from the nonprototypical debris transport and debris agglomeration that occurred when these methods for debris addition were used. The response to this issue was inadequate.

RAI 1B Summary:

Concentration of debris in the test flume with respect to agglomeration and settling.

RAI 1B Licensee Response:

The licensee stated that the heavier debris was added to the test flume prior to the lighter debris. This would result in less likelihood of the lighter debris being trapped by the heavier. In addition, the licensee conducted a test where all of the debris was added at or near the test strainer module.

RAI 1B NRC Staff Evaluation:

These points are valid for the aspects stated. However, agglomeration of debris can occur with a single type of debris and may not depend on relative density. For example, the NRC staff has observed agglomeration of apparently fine fibrous debris into large clumps that behaved as a single large piece rather than individual fibers. In this example, dumping an agglomerated mass of fiber onto the screen would not be expected to have the same effect on head loss as allowing the individual fibers to transport and collect on the strainer as would be more likely in the plant. The response to this issue was inadequate.

RAI 1C Summary:

The fibrous debris preparation and introduction with respect to prototypical sizing (transport and bed formation).

RAI 1C Licensee Response:

The licensee, in the response to RAI 1C, stated that finely shredded NUKON® was used as a surrogate for latent fiber.

RAI 1C Staff Evaluation:

The term "finely shredded" has little quantitative information associated with it. During NRC staff observations of testing (prior to 2008) at Alden labs, it was noted that the fibrous debris used in the testing was larger than considered prototypical for fine fiber. The NRC staff considers fibers in size classes 1-3 as defined in Section 3 of NUREG/CR-6808 "Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance," (ADAMS Accession No. ML030920542), to be adequate as a surrogate for fine fiber. Use of larger debris sizes would result in nonconservative test results. The licensee also stated that the fibers were mixed with water prior to introduction to the flume. This does not provide an adequate description of the concentration of fibrous debris in the test or compare it with what would be expected in the plant. The response to this RAI was inadequate.

RAI 1D Summary:

Flume velocity and turbulence.

RAI 1D Licensee Response:

The licensee provided the calculated flume velocity and flume turbulence.

RAI 1D NRC Staff Evaluation:

The flume conditions were not compared to the plant condition. It was noted that the flume velocity is much lower (by about 2 to 10 times) than velocities used by other plants that attempt to model the flow in the near field of the strainer. Because adequate agitation to maintain debris suspended was not provided and the flume velocity was likely nonconservative, it is probable that the head loss was affected nonconservatively. Therefore, the response to this issue was not adequate.

RAI 1E Summary:

Any near-field settling that occurred during the test.

RAI 1E Licensee Response:

The licensee stated that Test 6, which placed all debris on, or in the immediate vicinity of the strainer accounted for any near-field effects which could have altered the outcomes of the other tests. Because the head loss from Test 6 was slightly higher than the other test head losses it was selected as the limiting debris head loss.

RAI 1E NRC Staff Evaluation:

Placing debris directly onto a strainer is not likely to result in a conservative or even realistic head loss. Based on NRC staff observations of similar tests, Tests 1 - 5 probably had considerable near-field settlement. Therefore, the response to this issue was not acceptable.

RAI 1F Summary

Test scaling including debris amounts and strainer flow velocity.

RAI 1F Licensee Response:

The licensee provided the scaling for flow and debris amounts. The scaling was based on the ratio of flow areas between the plant strainer and the test strainer. This scaling factor was applied to both the flow rate and the debris quantities.

RAI 1F NRC Staff Evaluation:

The scaling factor generally includes a term for the miscellaneous debris assumed in the design-basis for the strainer. Had the miscellaneous debris term of 850 ft^2 (multiplied by the 0.75 factor) been included in the scaling, the flow rate and debris amounts would have been considerably higher. The licensee did adjust the scaling factor by about 70 ft^2, but the adjustment should have been 637 ft^2. The response to this issue was not acceptable without justification of the use of the lower area assigned to miscellaneous materials.

RAI 1G Summary:

How partial submergence of the strainer affects the scaling of flow and debris amounts.

RAI 1G Licensee Response:

The licensee stated that the test program was based on a large break LOCA (LBLOCA) that would result in a fully submerged strainer, and that scaling for a partially submerged strainer was not considered.

RAI 1G NRC Staff Evaluation:

Because a SBLOCA would probably result in a lower debris load, it might be acceptable to assume that large break conditions with a fully submerged strainer would bound small break conditions with a partially submerged strainer. However, the critical debris component for this strainer is the latent fiber which could be present for both large and SBLOCAs in an equal amount. Based on the response to RAI 3 (minimum pool submergence = 9.06 ft), it appears that the design of the strainer did not account for the possibility of partial submergence. However, the licensee did recognize that partial submergence was possible for a SBLOCA in their supplemental response, Section 3.f.2. Because significant portions of the strainer may not be submerged for a SBLOCA and the licensee has not shown that it considered the potential effects of partial submergence, the response to this RAI was not acceptable.

RAI 2 Summary:

Provide information that shows the applicability of the PCI, clean strainer head loss (CSHL) correlation to PWR strainers.

RAI 2 Licensee Response:

Following the issuance of the November 25, 2008, RAIs to the licensee the NRC staff received information from PCI justifying the CSHL correlation. In addition, the licensee provided information that corroborates the information provided by PCI.

RAI 2 NRC Staff Evaluation:

Based on the information received from PCI, the strainer vendor, the response to this issue is acceptable. The NRC staff compared the PCI CSHL correlation to the test data and Sequoyah's specific strainer design and found the correlation produced acceptable results.

RAI 3 Summary:

Clearly state the design inputs for the head loss testing and calculation and provide the basis for these inputs.

RAI 3 Licensee Response:

The licensee provided the inputs used in the design of the strainer.

RAI 3 NRC Staff Evaluation:

Although it appears that the actual minimum water level was not used as an input and it is unclear that the miscellaneous debris term was properly considered, the information provided is complete and correct. The minimum water level and miscellaneous debris terms were not required for the methodology used by the licensee. Other inputs adequately defined the design characteristics for the strainer. Therefore, the response to this RAI is acceptable.

RAI 4 Summary:

Provide the basis for the statement that a thin bed of fiber cannot form on the strainer considering the design-basis loading (200 lb latent debris) and design-basis strainer size (about 1,000 ft^2).

RAI 4 Licensee Response:

The licensee performed a calculation that showed that a theoretical bed of about 0.15 in. could form on the strainer if all of the assumed latent fiber reached the strainer and all of the assumed miscellaneous debris reached the strainer. However, the licensee argued that it would be unlikely for a thin bed to form on a strainer in the plant due to the complex strainer geometry, sump pool flow conditions, agglomeration of debris in the plant, and the presence of large debris on the strainer. The licensee stated that a test (Test 5) with 10 times the assumed latent debris amount was performed and a uniform bed did not result.

RAI 4 NRC Staff Evaluation:

The NRC staff finds that a 1/8 in. bed would likely not form on the Sequoyah 1 and 2 strainers. However, the NRC staff has seen the results of tests involving complex strainer designs that incurred significant head loss with about 1/20 in. of fiber (theoretical) added to the test after chemicals were added. In addition, based on the test scaling parameters, Test 5 should have added almost 1 in. of fiber (theoretical). For a test to add this amount of fiber and not result in a continuous fiber bed indicates that the test procedure was inadequate. A theoretical 1 in. of fiber added to any test utilizing accepted procedures would result in a continuous fiber bed. The NRC staff finds the response to this RAI adequate, but notes that the response points to the fact that the testing was not performed conservatively.

RAI 5 Summary:

Provide an evaluation of the performance of the strainer under partially submerged conditions.

RAI 5 Licensee Response:

The licensee stated for a fully submerged strainer that vortex formation would be precluded due to the size of the perforations (0.095 in.) on the surface of the strainer. The RAI response further stated that for a partially submerged strainer, operating at a flow rate of 12,900 gallons per minute (gpm), a minimum sump level of 4.18 ft is required to prevent drawing the core tube level down the level of the flow channel that connects the strainers to the ECCS suction. The minimum sump level was stated to be 5.04 ft.

RAI 5 NRC Staff Evaluation:

The response to the RAI did not provide assumptions or inputs for the vortex evaluation beyond those listed here. It was not clear that the calculation considered that a vortex could form within the core tube. The flow rate for the calculation was stated to be 12,900 gpm, but the design flow rate for the strainer is somewhat less than this so this input should be conservative. The RAI response also stated that numerous strainer qualification tests had been conducted for both fully and partially submerged strainers with acceptable results. However, these tests were not shown to be applicable or bounding for Sequoyah 1 and 2. The Sequoyah test appeared to be very short (about 3 disks high), so it was not clear that a partially submerged test could have been conducted during the Sequoyah testing. Without further details of the calculations and testing performed for the partially submerged condition, the response to RAI is inadequate.

RAI 6 Summary:

Provide an evaluation that shows that flashing across or within the strainer will not occur.

RAI 6 Licensee Response:

The response to RAI 6 addressed the LBLOCA case where the minimum strainer submergence is 1.91 ft. It was stated that the maximum head loss across the strainer would be 0.40 ft and that the head of water above the strainer would prevent flashing. A more limiting case could be the SBLOCA case with a lower strainer submergence.

RAI 6 NRC Staff Evaluation:

The NRC staff finds that when the strainer submergence is greater than the head loss across the strainer, flashing will not occur. A more limiting case, that was not evaluated, could be the SBLOCA case with smaller strainer submergence. Flashing across a partially submerged strainer may be prevented due to equalization of the pressure on both the inside and outside of the strainer and internal to the core tube during partial submergence. However, once the strainer is fully submerged head loss may result in flashing if the fluid is close to saturation. It was noted that the maximum design post-LOCA pool temperature is 190 °F for Sequoyah. If atmospheric pressure is maintained within the containment, this may provide adequate subcooling such that flashing is prevented. More realistically, the licensee could determine conservative margins to flashing by crediting the minimum predicted containment pressure and maximum sump temperature at various times throughout the event. It is also possible that a lower submergence scenario is very unlikely such that this question could be treated holistically. Without additional information, the response to RAI 6 was inadequate.

FINAL NRC STAFF REVIEW:

The final NRC staff review of head loss and vortexing is based on the licensee's RAI responses and supplemental information provided through June 27, 2014.

The licensee had previously responded acceptably to RAIs 2 and 3 in the head loss area. Therefore, RAIs 1 (multiple parts) and 4 through 6 remained open for the subsequent review. In order to close out the RAIs, the licensee performed updated head loss testing using procedures that were designed using NRC staff guidance for head loss testing. The licensee also reperformed sump level calculations to show that the strainer would be fully submerged within a reasonable time after switchover to the sump occurs. The responses to the remaining RAIs are discussed below.

Summary of RAIs 1A through 1G:

The RAI numbers correspond to the NRC RAIs dated October 14, 2009.

RAI 1 was split into several parts. Each part addresses one aspect of the strainer testing methodology and asks for information as to whether the methods used were conservative or prototypical when compared to the plant. A summary of the licensee's response and staff evaluation of each response are provided for each of the sub-issues. In order to address RAI 1 the licensee conducted updated strainer testing that was performed using procedures developed to meet NRC guidance for head loss testing. By using updated procedures to conduct the tests the licensee addressed each of the issues identified by RAI 1.

1. Provide the test protocol used for head loss testing and a justification that shows the following aspects of the testing were conservative or prototypical:

RAI 1A Summary:

Addition of debris to the test flume prior to the starting of the recirculation pump.

RAI 1A Licensee Response:

In response to RAI 1A, the licensee described the updated test methodology. The licensee stated that the debris was added to the flume with the recirculation pump running. In addition, the test facility was designed to maintain the debris in suspension and well mixed with water during the addition process. These test features served to minimize agglomeration and maximize transport without disturbing the debris bed. RMI was not added to the test because it was shown not to transport to the strainer. The licensee provided the test report that discussed the testing.

RAI 1A NRC Staff Evaluation:

Because the licensee performed new tests that used test methods that meet the NRC guidance for strainer head loss testing, the response to RAI 1A is acceptable.

RAI 1B Summary:

Concentration of debris in the test flume with respect to agglomeration and settling.

RAI 1B Licensee Response:

The licensee stated that only fine fibers were used in the testing and that adequate dilution was ensured so that no clumps of debris were observed. The RAI response also stated that the recirculation pump was operating prior to debris being added to the test and that the debris was added in order from the most transportable to least transportable. The debris was added using a pump and injected below the water surface to prevent air entrainment during the debris introduction.

RAI 1B NRC Staff Evaluation:

The NRC staff has witnessed tests at the facility and observed the methods used to introduce debris to the test facility. The licensee's description of the debris addition procedure is consistent with staff observations of debris introduction that are acceptable to the staff and meet staff guidance. Therefore the response to RAI 1B is acceptable.

RAI 1C Summary:

The fibrous debris preparation and introduction with respect to prototypical sizing (transport and bed formation).

RAI 1C Licensee Response:

The licensee stated that finely shredded NUKON® was used as a surrogate for latent fiber and that the fiber was prepared to achieve the form discussed in NUREG/CR-6885. In addition the fibers were mixed and diluted to prevent clumping or agglomeration.

RAI 1C Staff Evaluation:

The fiber used in NUREG/CR-6885 was processed in a blender to assure that it met the characteristics expected of fine fiber. Blender prepared fiber is generally conservative in size compared to staff expectation for fine fiber. In addition, the staff has witnessed tests at the facility in which the Sequoyah testing was performed. The debris preparation and introduction procedures at the facility, and as described in the RAI responses, meets NRC guidance. Therefore, the response to RAI 1C is acceptable.

RAI 1D Summary:

Flume velocity and turbulence.

RAI 1D Licensee Response:

The licensee stated that the test tank was comprised of two sections leading to the strainer module. An upstream section included high energy mixing to ensure that the fiber remained suspended. A middle debris suspension section allowed the debris to transport to the strainer without settling, but also did not prevent the debris bed from forming prototypically on the strainer.

RAI 1D NRR Staff Evaluation:

The flume design and flow conditions met NRC guidance for conducting head loss testing. The settling of debris was minimized while the debris bed on the strainer was not disturbed by the agitation used to maintain the suspension of debris. Therefore the response to RAI 1D is acceptable.

RAI 1E Summary:

Any near-field settling that occurred during the test.

RAI 1E Licensee Response:

The licensee stated settling of debris was prevented by the design of the test facility as described in the response to RAI 1D.

RAI 1E NRC Staff Evaluation:

The flume design and flow conditions met NRC guidance for conducting head loss testing. The settling of debris was minimized while the debris bed on the strainer was not disturbed by the agitation used to maintain the suspension of debris. Therefore the response to RAI 1E is acceptable.

RAI 1F Summary:

Test scaling including debris amounts and strainer flow velocity.

RAI 1F Licensee Response:

The licensee stated that debris quantities and flow rates for the testing were scaled based on the ratio of the surface area of the test strainer to that of the actual area of the strainer installed in the plant. The surface area of the plant strainer was reduced by 200 ft^2 to ensure that the ratio was conservative. The licensee justified eliminating the adjustment for miscellaneous debris by performing transport tests for tags and labels to verify that they would not transport to the strainer.

RAI 1F NRC Staff Evaluation:

The scaling used for the testing was performed in accordance with staff guidance for strainer testing. Using the ratio of the plant strainer to the test strainer is the recommended method. In addition, the staff accepts transport testing of miscellaneous debris to determine whether it will transport to the strainer. If the miscellaneous debris does not transport, the licensee does not need to include a correction for that type of debris. Since the licensee showed that the miscellaneous debris would not transport and they included a 200 ft^2 sacrificial area in the scaling factor the scaling was conservative. Therefore, the response to RAI 1F is acceptable.

RAI 1G Summary:

How partial submergence of the strainer affects the scaling of flow and debris amounts.

RAI 1G Licensee Response:

The licensee stated that they revised the sump level calculation for a SBLOCA so that it more closely reflects plant conditions. For the limiting SBLOCA, low head safety injection and the accumulators do not inject into the RCS. It also assumes that the RCS is filled thus limiting the available inventory for the sump and resulting in lower strainer submergence. The updated calculation used more realistic assumptions regarding water holdup in the reactor cavity by using a time based filling for that volume. The updated calculation also includes ice melt and condensing steam in the inventory. Ice melt and condensation are calculated using a thermal hydraulic code. Based on the updated time dependent sump level calculation, at the time of switchover to sump recirculation, 4.36 ft of the possible 6 ft wetted height of the strainers are covered with water. Full submergence of the strainer occurs in less than 4.7 minutes after ECCS is realigned to the sump. CSS continues to draw from the refueling water storage tank (RWST) resulting in a very low flow rate through the strainer during this time. Because the flow rate is low during this period, there will be little debris accumulation on the strainer and head loss across the strainer will be very small. The strainers are fully submerged by at least 1 ft. before the CSS pumps are aligned to the sump.

RAI 1G NRC Staff Evaluation:

The NRC staff agrees that the partial submergence of the strainers will not have an adverse effect on flow to the ECCS pumps for the short period of time between ECCS swap over and full submergence. The NRC staff evaluation of this issue is based on the small amount of flow passing through the partially submerged strainer, its low velocity through the strainer, and the small amount of debris available for blocking areas of the strainer. Because the strainer is only partially submerged for a very short time and the flow rate through the strainer remains very low until the submergence is 1 ft or greater the staff finds the response to RAI 1G acceptable.

RAI 4 Summary:

Provide the basis for the statement that a thin bed of fiber cannot form on the strainer considering the design-basis loading and design-basis strainer size.

RAI 4 Licensee Response:

The licensee stated that they had performed a conservative thin bed test. The licensee described the methods used to perform the test and included the test report as part of the submittal as Attachment 3. The test was designed to determine whether a thin bed could occur on the strainer. At the end of the test it was observed that the strainer was not covered with a uniform thin bed. The test included a scaled equivalent of 15 lb of latent fiber. The test resulted in a debris head loss of about 2.5 ft. The head loss occurred when the fiber was added to the test. No significant increase in head loss occurred when chemicals were added.

RAI 4 NRC Staff Evaluation:

The thin bed test was performed in accordance with NRC staff guidance for strainer head loss testing. The test showed that the strainer can accommodate the assumed fibrous debris load (15 lb) for the strainer without excessive head loss or even developing a full filtering bed. The NRC staff finds that the strainer can accommodate the design-basis debris load and that a thin bed made up of this load is accommodated. Therefore the response to RAI 4 is acceptable.

RAI 5 Summary:

Provide an evaluation of the performance of the strainer under partially submerged conditions.

RAI 5 Licensee Response:

The licensee referenced the response to RAI 1G.

RAI 5 NRC Staff Evaluation:

Based on the response to RAI 1G and as documented above, the NRC staff concluded that operation of the Sequoyah strainer under partially submerged conditions for a short period of time is acceptable. Therefore the response to RAI 5 is acceptable.

RAI 6 Summary:

Provide an evaluation that shows that flashing across or within the strainer will not occur.

RAI 6 Licensee Response:

The licensee referenced the response to RAI 1G. The submergence of the strainer is expected to be greater than 1 ft prior to the switch over to CS recirculation for the most limiting conditions. In addition, the RAI response states that flow through the strainer is low. The licensee concluded based on the minimum calculated water levels that flashing across the strainer is precluded. The licensee had previously stated (in its initial GL 2004-02 response) that the maximum sump temperature is 190 °F.

RAI 6 NRC Staff Evaluation:

The NRC staff concluded that flashing will not occur across the strainer because strainer submergence will be adequate before enough debris to cause a significant head loss can transport to and collect on the strainer. Additionally, the maximum sump temperature of 190 °F provides for significant subcooling that increases the margin to flashing significantly. Therefore the response to RAI 6 is acceptable.

In the June 27, 2014, letter, the licensee stated that the amount of fibrous debris in the plant is limited based on the in-vessel limit of 15 grams per fuel assembly. This is equal to 14 lb of fiber in containment when a strainer bypass factor of 45 percent is applied. The 45 percent bypass factor is considered to be conservative by the NRC staff. The licensee is a participant in the PWROG work to show that larger amounts of fiber can be ingested into the core without adverse effects on long-term core cooling. If higher in-vessel fiber amounts are shown to be acceptable, Sequoyah intends to increase their allowable containment fiber limit to 15 lb. Fifteen lb is the amount used in the strainer testing discussed above. Both the current limit of 14 lb and the potential future limit of 15 lb are significantly higher than the amount of latent fiber estimated to be present in the Sequoyah containments.

The licensee also stated that they were referencing the clean plant criteria for closure of the issue. The use of the clean plant criteria is justified if a licensee's strainer area is large enough to ensure that no more than 1/16 in. theoretical fiber bed can form on the strainer based on the fiber in containment and the design strainer area. The design-basis debris load is 15 lb (6.25 ft^3) and the design strainer area is 1,409 ft^2 after accounting for the sacrificial area. This results in a potential theoretical bed thickness of 0.053 in., which is less than 1/16 in.

The NRC staff has reviewed the results of the testing provided with the final RAI responses. It appeared that some of the temperature scaling applied to the results was questionable considering that a full filtering bed did not form during the design-basis test and a flow sweep was not performed to determine whether the scaling is appropriate. However, the NRC staff concluded that the testing was conservative because it included a significantly larger fibrous debris term than actually resides in the containments at Sequoyah, included 200 ft^2 of sacrificial area, and the resulting head losses were low. Additionally, the licensee has shown that the clean plant criteria can be applied to the strainer, which would justify the strainer design without performing plant-specific testing to validate that the head loss will be minimal. Therefore, the staff concluded that the Sequoyah 1 and 2 strainer design is acceptable.

NRC STAFF FINAL CONCLUSION:

Based on the test results provided by the licensee, and the application of the clean plant criteria to the head loss and vortexing evaluation, the NRC staff concluded that the head loss portion of the analysis has been completed adequately. The other information provided by the licensee, either previously or in the recent submittals, provide adequate documentation that the strainer will perform its function during any required recirculation operation at Sequoyah. For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. The NRC staff also considered that the NPSH margins for the ECCS and CS pumps are significantly larger than the head loss measured across the strainer in the design-basis test. Therefore, the NRC staff concludes that the head loss and vortexing evaluation for Sequoyah acceptable. The NRC staff considers this item closed for GL 2004-02.

In addition to the determination that the strainer will function as required under design-basis conditions, the staff understands that the licensee may increase its fibrous debris limit in containment from 14 lb to 15 lb if ongoing industry in-vessel testing supports such an increase. Because the strainer was tested using a scaled amount of debris equal to 15 lb, and the 15 lb limit also supports the clean plant criteria, the NRC staff finds that it is acceptable, from a strainer perspective, to increase the design-basis fibrous debris load within containment to 15 lb.

For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically.

Therefore, the NRC staff concludes that the head loss and vortexing evaluation for Sequoyah acceptable. The NRC staff considers this item closed for GL 2004-02.

9.0 NET POSITIVE SUCTION HEAD

The objective of the NPSH section is to calculate the NPSH margin for the ECCS and CSS pumps that would exist during a LOCA considering a spectrum of break sizes.

INITIAL NRC STAFF REVIEW:

The initial NRC staff review is based on documentation provided by the licensee through February 29, 2008.

The licensee presented a summary of their NPSH analyses. The discussion of the methodology, and the assumptions and parameters in the NPSH analyses was clear. Each of the technical issues specified in the GL content guidance document was addressed by the licensee. Detail concerning the parameters, assumptions, and conservatisms in the NPSH and minimum flood level analyses was presented. The methodology used was standard industry practice for the calculation of NPSH available ($NPSH_A$) and NPSH margin. The NPSH analyses were performed with conservative and realistic assumptions.

The licensee provided the pump flow rates used in the Sequoyah 1 and 2 sump recirculation NPSH calculations for both LBLOCA and SBLOCA accidents. Individual residual heat removal (RHR) and CSS flow rates for sump recirculation and the total recirculation flow rates were presented, both for LBLOCA and SBLOCA conditions. The assumed flow rates for the RHR pump during recirculation were 5500 gpm for LBLOCA and 2460 gpm for SBLOCA. The CSS flow rates were 5,169 gpm for a LOCA in Unit 1 and 5,068 gpm for a LOCA in Unit 2. Total recirculation flow rates were nominally 10,600 gpm for LBLOCA and 7,600 gpm for SBLOCA. The sump water temperature used in the NPSH analyses was 190 °F, stated by the licensee to be the maximum post-LOCA pool temperature.

A number of assumptions used in the calculations for the ECCS and CSS flow rates, both for LBLOCA and SBLOCA, were given. Conservative modeling techniques and design inputs were used to provide bounding results. These included the following:

- RHR pumps in each train were operating at the design maximum flow to maximize ECCS flow for a LBLOCA.

- For a SBLOCA, primary system pressure may remain high and prevent RHR flow to the primary system. Therefore maximum RHR flow was established as the total run-out flow of both trains of safety injection pumps and centrifugal charging pumps.

- Flow through the CSS was calculated using inputs that maximized the flow.

The required NPSH values for the pumps were obtained from the vendor for the Sequoyah 1 and 2 ECCS and CSS pumps. The values were based on factory NPSH testing in accordance with industry standards; typically the 3 percent head drop criterion was used for this type of testing. Suction piping head losses, which included friction and form losses, were calculated with the MULTIFLOW 1.21 computer code. The licensee stated that this calculation used conservative inputs and parameters to maximize the flows in order to establish bounding head losses in the NPSH analyses.

A discussion was provided by the licensee to describe the system response scenarios for LBLOCA and SBLOCAs, and to describe the operational status for each ECCS and CSS pump before and after the initiation of recirculation. The startup sequence upon receipt of a safety injection signal was presented, with injection from the RWST into the primary system cold legs. When the RWST water level reached a low-level setpoint, switchover to ECCS recirculation mode of operation occurred. Switchover to recirculation was described as a semiautomatic process. After ECCS recirculation operating mode is established, the RHR pumps would inject into the primary system cold legs and supply water to the suction of the Centrifugal Charging Pumps and the Safety Injection pumps. Manual operator action would be taken to stop and isolate the CSS pump suction from the RWST, open the CSS pump suction to the containment sump, and then restart the CSS pumps in recirculation mode. The licensee stated that the limiting single failure for those transients that require containment sump recirculation at Sequoyah 1 and 2 is the complete loss of one train of ECCS equipment.

The containment post-LOCA water level was determined by considering the volumes occupied by structures and the cavity volumes inside the containment that are available to collect water for recirculation to the minimum volume of water discharged during the event. The sump and lower containment volumes available to collect recirculation inventory were established by calculation of the available free volumes in the areas that communicate with the discharge sources and the recirculation sump intake. Sources of water were identified based on the nature of the event and the safety system responses. The sources included primary system inventory, cold leg accumulator inventory, RWST inventory and ice condenser ice melt inventory. Discharge volumes that were unavailable to the sump recirculation volume included water held up in the reactor cavity, water held up on the operating deck floor, water in the upper containment atmosphere, water held up in the accumulator rooms, and water in the containment spray piping. Based upon the consideration of a number of assumptions, minimum water depths were calculated. Considerations that could reduce the water contribution to the containment sump were taken into account when determining the minimum water level in the containment post-LOCA. Among these were an empty spray pipe, water droplets, condensation, and holdup on horizontal and vertical surfaces. These assumptions were reviewed and were found to be realistic and conservative.

The sources of water and the contributions of each source to the minimum water level in containment were provided. The sources credited were as follows:

Water source	LBLOCA	SBLOCA
Primary system inventory	68,008 gallons	0 gallons
Cold leg accumulator	30,460 gallons	0 gallons
RWST inventory	196,241 gallons	196,241 gallons
Ice melt inventory	131,662 gallons	0 gallons

The total inventories reported were 426,321 gallons of water for LBLOCA and 196,241 gallons of water for SBLOCA.

In determining the available NPSH, credit was not taken for the containment accident pressure. The Sequoyah 1 and 2 containment sump operation NPSH calculations assumed that the containment pressure was constant at the minimum internal building pressure of 14.3 pounds per square in. absolute (psia). This calculation also assumed that the sump temperature was constant at 190 °F, resulting in a pump suction vapor pressure of 9.43 psia. The NPSH margins for Sequoyah 1 and 2 sump recirculation operation were as follows:

Pump	LBLOCA margin	SBLOCA margin
Unit 1-A RHR pump	6.7 ft	25.5 ft
Unit 1-B RHR pump	7.7 ft	25.9 ft
Unit 1-A CS pump	15.4 ft	14.6 ft
Unit 1-B CS pump	14.4 ft	13.2 ft
Unit 2-A RHR pump	6.9 ft	25.7 ft
Unit 2-B RHR pump	7.8 ft	26.0 ft
Unit 2-A CS pump	15.9 ft	15.1 ft
Unit 2-B CS pump	14.9 ft	13.7 ft

The licensee identified the following conservatisms used in the NPSH calculations:

- o The sump water vapor pressure was at the maximum sump water temperature.
- o Credit was not taken for containment accident pressure in determining the $NPSH_A$.
- o The licensee used maximum flow rates in the analyses of the pump suction head loss and the required NPSH ($NPSH_R$).
- o The licensee minimized the volumes of the various sources of water, and maximized the mechanisms and volumes for water entrapment.

The licensee did not provide sufficient basis to demonstrate that the NPSH single-failure analysis was adequate. It is unclear why the loss of one train leads to bounding conditions for NPSH, and also that any other single-failure scenarios were considered by the licensee. The NRC staff did not request additional information because of the relatively large NPSH margins for the pumps in comparison to the expected debris bed head loss, and the fact that the partially submerged screen case has a margin significantly less than the minimum NPSH margin (e.g. 2.5 ft versus 6.7 ft).

<u>FINAL NRC STAFF REVIEW</u>:

The final NRC staff review is based on the licensee's RAI responses and supplemental information through July 10, 2014.

The licensee recalculated the sump water level for the SBLOCA was described in the response to RAI 1G above. This calculation revised the assumption that no ice melt would contribute to the SBLOCA sump inventory. The updated evaluation calculates a realistic amount of ice melt and steam condensation and adds it to the sump inventory. The more realistic assumptions are acceptable and the SBLOCA sump level calculation still contains conservatism to ensure that the calculated sump levels will be attained.

No RAIs were identified through initial NRC staff review. With the exception of the changes to the SBLOCA level discussed above, no changes to the original information were submitted by the licensee. Thus this area remains adequately addressed.

<u>FINAL NRC STAFF CONCLUSION</u>:

For the NPSH area, the licensee has provided information such that the NRC staff has reasonable assurance that it has been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the NPSH evaluation for Sequoyah 1 and 2 is acceptable. The NRC staff considers this area closed for GL 2004-02.

10.0 <u>COATINGS EVALUATION</u>

The objective of the coatings evaluation section is to determine the plant-specific ZOI and debris characteristics for coatings for use in determining the eventual contribution of coatings to overall head loss at the sump screen.

<u>NRC STAFF REVIEW</u>:

The NRC staff review is based on documentation provided by the licensee through February 29, 2008.

The content guide called for the dry film thicknesses for coating to be provided, but this information was not listed in the licensee's response. Although missing, the NRC staff does not consider this a significant gap in information since conservative quantities of coating debris were provided.

The ZOI used by the licensee was 10D, which was based on the NRC SE approving NEI 04-07. Coatings in the ZOI and all unqualified coatings in containment failed as fine particulate to maximize transport.

Based on testing performed, the licensee did not observe a thin bed with coatings debris treated as particulate. In additional testing, the licensee introduced paint chips of a size equivalent to the area of the sump screen openings to maximize head loss for strainer testing. This is acceptable based on the NRC SE approving NEI 04-07. The testing included a particulate and chip case to conservatively cover the two extremes for coating debris. The surrogate material used for testing is acceptable to the NRC staff since the particle size and density are similar to the coating particles.

The licensee's coating assessment program is acceptable to the NRC staff since the licensee's assessment is conducted during each refueling outage, is conducted by qualified personnel, and if degraded coatings are identified, these areas are documented and additional tests and remediation may be performed.

<u>NRC STAFF CONCLUSION</u>:

For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Therefore, the NRC staff concludes that the coatings evaluation for Sequoyah 1 and 2 is acceptable. The NRC staff considers this item closed for GL 2004-02.

11.0 <u>DEBRIS SOURCE TERM</u>

The objective of the debris source term section is to identify any significant design and operational measures taken to control or reduce the plant debris source term to prevent potential adverse effects on the ECCS and CSS recirculation functions.

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through February 29, 2008.

Design and administrative controls are in place at Sequoyah to ensure that potential quantities of postaccident debris are maintained within the bounds of the analyses and design bases that support EGGS and CSS recirculation functions.

The licensee listed summaries of the procedures and engineering specifications that constitute the present containment material control and inspection requirements at Sequoyah that pertain to ensuring operability of the containment sump.

Collectively, these documents provide the technical and programmatic controls necessary to ensure that design change, maintenance, and modification activities are conducted in a manner that assures operability of the containment sump. Additionally, design and operational refinements suggested by NEI 04-07 (Section 5) and the associated NRC SE (Section 5.1) were reviewed relative to the advanced design containment sump strainer modification at Sequoyah. Based on the operating margins provided by the advanced design sump strainers for the present debris load, no replacement or modification (e.g., jacketing or banding) of insulation in containment was required to reduce the debris burden on the strainers. Similarly, no changes to the containment coatings program were required to remove or replace coatings inside containment.

NRC STAFF CONCLUSION:

For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. The licensee has provided information necessary for the NRC staff to conclude that the debris source term is controlled to an acceptable level such that the recirculation function will not be adversely affected. Therefore, the NRC staff concludes that the debris source term evaluation for Sequoyah is acceptable. The NRC staff considers this item closed for GL 2004-02.

12.0 SCREEN MODIFICATION PACKAGE

NRC STAFF REVIEW:

The objective of the screen modification package section is to provide a basic description of the sump screen modification.

The NRC staff review is based on documentation provided by the licensee through February 29, 2008.

The licensee provided a basic description of the major features of the sump screen modification, in addition to a listing rerouting of piping and other components modifications necessitated by the sump strainer modification. A summary of the modifications to the ECCS sump strainer installations appears below:

The licensee's responses provided a basic description of the major features of the new sump strainers. They are PCI "stacked disk" strainer design. The strainer module "stacked disks" are nominally 5/8 in. thick with a 1 in. separation between adjacent disks. The interior of the disks contain rectangular wire stiffeners for support. They are configured as a "sandwich" made up of three layers of wires. The disks are completely covered with perforated plate having 0.095 in. diameter holes. Each strainer module has a central flow channel. The strainer assemblies are comprised of two vertical single module seven-disk stacks and three vertical six-module, six-disk stacks mounted over the sump pit. The sumps are located below and just outboard of the Loop 4 crossover leg piping. The taller strainer disk stack assemblies are not expected to be completely submerged during a small break LOCA. The original grating, baffle plates and screens located within the sump pit remain in place to ensure no vortex formation. The total flow area of the new strainers in each unit is 1,609 ft^2. The strainers are constructed entirely of stainless steel materials.

The objective of the new strainer design is to provide acceptable flow with minimal head loss at the specified debris loads and to ensure adequate NPSH to the RHR/CSS pumps during the post-LOCA recirculation phase. The new strainer offers approximately 1,609 ft^2 of surface area versus the original ~51 ft^2 total for the original sump screens.

<u>NRC STAFF CONCLUSION</u>:

The licensee has provided information necessary for the NRC staff review. Based on its review the NRC staff finds the licensee has provided sufficient information as required by GL 2004-02, and considers this item closed for GL 2004-02.

13.0 SUMP STRUCTURAL ANALYSIS

The objective of the sump structural analysis section is to verify the structural adequacy of the sump strainer including seismic loads and loads due to differential pressure, missiles, and jet forces.

<u>NRC STAFF REVIEW</u>:

The NRC staff review of Section 3k, Sump Structural Analysis, of the licensee's February 29, 2008, submittal, has led to the conclusion that the licensee has adequately addressed the information requested by the Revised Content Guide for GL 2004-02 Item 2(d)(vii), with one exception related to the American Society of Mechanical Engineers (ASME) Code Edition used for the strainer design.

The licensee stated replacement strainers and flow plenum assemblies meet the applicable, allowable stress requirements of the American Institute of Steel Construction (AISC) Manual of Steel Construction, 7^{th} Edition, the ASME Boiler & Pressure Vessel (B&PV) Code, Section III, and American National Standards Institute/American Welding Society (ANSI/AWS) D1.6, "Structural Welding Code-Stainless Steel." Furthermore, the design and analysis of the concrete anchor bolts were stated to meet the requirements of TVA Design Standard DS-C1.7.1, "General Anchorage to Concrete."

The licensee's submittal further stated that a combination of GT STRUDL and ANSYS Computer Program finite element analysis models and manual calculations were used to evaluate the replacement sump strainers and flow plenum assembly. The maximum stresses in each of the evaluated members and welds were then compared with the appropriate AISC Manual of Steel Construction, 7th Edition, allowable stress limits to show compliance. The licensee also stated that there are certain instances where the AISC manual does not provide adequate guidance for the qualification of particular components. For these cases other codes or standards were employed accordingly. The most significant of these cases are the use of the equations from Appendix A, Article A-8000 of the ASME B&PV Code, Section III, 1989 Edition, which deals with perforated plate stresses, and the use of Structural Engineering Institute/American Society of Civil Engineers (SEI/ASCE) 8-02, "Specification for the Design of Cold-Formed Stainless Steel Structural Members," for the qualification of thin-gauge and cold-formed stainless steel sections.

In the submittal, the licensee stated that the analysis for the replacement sump strainers and the flow plenum had considered the following loads: dead load of the structure, thermal effects, differential pressure, and seismic loads for both an operational basis earthquake and a safe-shutdown earthquake. The licensee stated that the consideration of hydrodynamic loads was precluded by the plant design-basis. That is to say, the assumption of a seismic event following a LOCA is not part of Sequoyah's design-basis. The submittal also stated that the strainers were not subject to jet impingement, pipe whip, or missile impacts based on the location of high-energy piping with respect to the replacement strainers.

An evaluation of the strainers considering reverse flow was not performed as the licensee stated that back-flushing is not credited in the overall analysis.

The information provided by the licensee shows that the sump structural evaluation contains inherent conservatism by complying with plant guidance and industry standards (e.g., AISC, ASME B&PV Code, and plant-specific design criteria). The licensee stated that the allowable stresses for carbon steel which are provided in the AISC specification were utilized to qualify the stainless steel structure. At low temperatures (the maximum accident temperature is 190 °F), this is a conservative approach. Furthermore, the AISC standard allows an increase of 33 percent in allowable stresses for steel due to seismic or wind loadings. This increased allowable was not credited according to the licensee's submittal. For these reasons, the licensee has provided sufficient information to show that a level of conservatism exists and the intent of the Revised Content Guide for GL 2004-02 Item 2(d)(vii) has been met.

A subsection of the licensee's submittal titled "Design Codes" lists the ASME B&PV Code, 2004 Edition with 2005 Addenda, as being utilized in the qualification of the replacement sump strainers and flow plenum. At the time of the initial review, the 2004 Edition with 2005 Addenda was not endorsed by 10 CFR 50.55a. The licensee stated that the AISC 7th Edition was the primary standard for fabrication and design, however, where the AISC did not provide adequate guidance, other standards were used. It is unknown to the staff, to what extent the 2004 Edition of the ASME code was utilized. Furthermore, it is unknown if the portions of the ASME code that were utilized vary from those editions that are currently endorsed by the 10 CFR 50.55a. In the second set of RAIs issued by the NRC, the licensee was requested to provide justification and/or re-evaluation for discrepancies, if any, between the applicable portions of the 2004 Edition of the ASME Code that were used in the sump structural analysis and the respective Code Editions that are currently endorsed by the NRC in 10 CFR 50.55a.

By letter dated February 23, 2009, the licensee responded to the RAI. Based on the NRC staff's review of the licensee's response, the NRC staff concludes that the licensee has adequately addressed the information requested by Section 3k, Sump Structural Analysis, of the Revised Content Guide for GL 2004-02 Item 2(d)(vii). The licensee stated that the 2004 Edition through 2005 Addenda of the ASME Code was originally specified for any vertical or horizontal strainer supports. Based on the results of the original structural analysis, no horizontal or vertical supports were required or included in the strainer design; therefore, the 2004 Edition through the 2005 Addenda of the ASME Code was not used. Section III of the ASME Code was used in the calculation of perforated plate stress; however, the 1989 Edition of the ASME Code was used, which is a version endorsed in 10 CFR 50.55a. Therefore, no reconciliation of the later ASME Code Edition is necessary.

<u>NRC STAFF CONCLUSION</u>:

This provides the NRC staff with reasonable assurance that the sump strainer assemblies will remain structurally adequate under normal and abnormal loading conditions such that the assemblies will be able to perform their intended design functions. The NRC staff considers this item closed for GL 2004-02.

14.0 UPSTREAM EFFECTS

The objective of the upstream effects assessment is to evaluate the flow paths upstream of the containment sump for holdup of inventory, which could reduce flow to the sump.

<u>NRC STAFF REVIEW</u>:

The NRC staff review is based on documentation provided by the licensee through February 29, 2008.

Containment walkdowns were performed in accordance with the guidance of NEI 02-01. These walkdowns identified three potential choke-points that could prevent adequate water inventory from reaching the containment sump. The potential choke-points are the two 14 in. diameter refueling canal drains and a drain in accumulator rooms 3 and 4.

The drains in the accumulator room allow the small amount of spray flow that directly hits the air return fans to be returned inside the polar crane wall. Curbs are present in the upper compartment around the fan suction that prevents spray water on the refueling floor from spilling through the fans. Thus, the only debris from the spray system entering the accumulator rooms is very small debris that has traveled through the strainers. Neither the upper compartment nor the accumulator rooms are subjected to high energy jets. The only debris in these compartments is failed coatings. The size of the failed coatings or debris that passes through the spray pumps is small and will not block any of these drains. Reflective metal insulation debris, large or small, will not be present to block these drains. It is therefore concluded that there will be no water inventory holdup or diversion due to debris blockage at choke-points.

Additionally, an inspection for non-LOCA generated material that could potentially obstruct recirculating water is conducted by the licensee as part of the containment cleanliness inspection program prior to restart from an outage. The controlling procedure specifically addresses the need to assure that the containment is free of all items that could be washed to the sump. Sequoyah 1 and 2 are ice condenser plants with a free standing steel containment. There are four distinct regions within the containment. The lower compartment contains the reactor coolant system and the LOCA boundary. The perimeter of the lower compartment is the containment floor, the right circular cylinder concrete crane wall, and the divider barrier at the top. The emergency sump is in the lower compartment. The dead-ended compartments are outside the crane wall and extend to the containment shell. The divider barrier is the top of the dead-ended compartments. The ice condenser is located outside the crane wall and provides a flow path for steam and noncondensable gases between the lower compartment and the upper compartment. The upper compartment is an open volume that serves as a reservoir for noncondensable gases during a high energy line break in the lower compartment.

The CSS discharges into the upper compartment. The spray flow is returned to the lower compartment through two drains in the floor of the refueling canal. There are no high energy pipes in the upper compartment or the ice condenser. The containment sump is located near RCS loop 4. The sump is a pit in the containment floor. The suction piping is located approximately 10 ft below the floor elevation. The penetrations in the crane wall have been sealed to an elevation of 13 ft above the containment floor. During a LOCA, water fills the sump from the refueling water storage tank by injection from the ECCS system and CSS and from water due to ice melt. The lower compartment fills first. After the water level reaches just over 13 ft, water begins to flow into the dead-ended regions. Once this water enters the dead-ended region, it no longer actively communicates with the lower compartment sump. Thus, any debris generated in or carried into the dead-ended regions will not contribute to sump screen blockage or downstream effects.

No exposed fibrous material is used in the Sequoyah 1 and 2 containments in areas that are subjected to high energy jets, containment spray or ice condenser melt water flow, or submergence in the active sump pool. Stainless steel RMI is used on the RCS and other insulated piping in the lower compartment. Non-metallic tape, tags and labels in the upper, lower, and ice condenser compartment are a post-LOCA debris source.

A three-dimensional (3D) CFD analysis of the Sequoyah 1 and 2 containments was performed to determine flow direction, velocity, and turbulence in the sump pool. The analyses were performed using the FLOW 3D computer code. The volume of the RMI ZOI is 1,690,000 ft^3. The entire volume of the lower compartment is approximately 248,000 ft^3. Thus, the reflective ZOI does not have a physical meaning.

NRC STAFF CONCLUSION:

For this review area, the licensee has provided information, such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Since the licensee has shown that the drainage paths from the ice condensers and refueling canal cannot credibly become blocked the NRC staff concluded that the upstream effects area has been adequately addressed by the licensee. The NRC staff considers this item closed for GL 2004-02.

15.0 DOWNSTREAM EFFECTS - COMPONENTS AND SYSTEMS

The objective of the downstream effects, components and systems section is to evaluate the effects of debris carried downstream of the containment sump screen on the function of the ECCS and CSS in terms of potential wear of components and blockage of flow streams.

NRC STAFF REVIEW:

The NRC staff review is based on documentation provided by the licensee through February 29, 2008.

Sequoyah Units 1 and 2 are low-fiber plants. There is no fibrous or Min-K insulation installed in the plant that can transport to the ECCS sump during a LOCA. The quantity of latent fiber and debris, failed coatings, and failed RMI insulation assumed by the licensee is very conservative. A latent debris walkdown assessed the latent debris at 24.5 lb with only a few latent fibers found. However, the licensee assumed 200 lb of latent debris in their analytical assessments. Of the 200 lb, 15 percent or 30 lb (12.5 ft^3) of the debris was assumed to be fibrous. The licensee's GL 2004-02 supplemental response contains a detailed description of the methods used by the licensee to evaluate the downstream effects of debris that bypass the ECCS sump strainers. The licensee stated that the evaluation followed the methods of TR-WCAP-16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191" Revision 1, and the corresponding NRC SE, without exception. The licensee evaluated ECCS and CSS component downstream of the strainers (e.g., valves, orifices, spray nozzles, residual heat removal system pumps, CSS pumps, instruments, and heat exchanger tubing) for blockage and wear. The licensee also evaluated the safety injection pumps and centrifugal charging pumps for erosive and abrasive wear. The licensee concluded that the performance of the components would not be affected by the ingested debris.

The downstream effects of debris ingested during containment sump recirculation operation were evaluated by the licensee using the methods described in Revision 1 of TR-WCAP-16406-P with limitations contained in the associated NRC SE. The evaluation addressed the effect of debris ingestion on equipment in the ECCS and CSS systems, including valves, pumps, heat exchangers, orifices, spray nozzles, and instrumentation. The equipment evaluations included erosive wear, abrasion, and potential blockage of flow paths. No exceptions were taken to the evaluation methods contained in the WCAP. The licensee stated that the evaluations included the following significant assumptions.

General Assumptions:

1. The mission time for the Sequoyah ECCS and CSS equipment was assumed to be 30 days.

2. For the pump wear evaluation, an industry accepted wear ring gap increase of up to three times the design clearance was assumed to have no significant impact on the hydraulic performance of the ECCS and CSS pumps.

3. Fibrous debris and RMI particulate debris were assumed to be greater than 400 μm and hence were assumed to deplete per the adjusted wear model presented in the TR-WCAP-16406-P.

4. All other particulate debris and the coatings debris within the ZOI of the break were assumed to be less than 100 µm (due to the characteristic sizes) and, therefore, were conservatively assumed not to deplete.

5. Unqualified coatings outside of the ZOI were assumed to fall in a size distribution with 94.0 percent of the unqualified coatings debris greater than 400 µm, 4.5 percent in the 400 µm to 101 µm size range, and 1.5 percent less than or equal to (≤) 100 µm. The size of the unqualified coatings ≤ 100 µm is assumed to be 50 µm on average.

Erosive and Abrasive Model Assumptions:

1. The abrasive and erosive wear on pumps in service during normal plant operation was assumed to not exceed 3.0 thousandth of an in. (mils).

2. A debris depletion factor of 0.07 hr^{-1} was assumed for both abrasive and erosive wear for in Equation 7.2-1 from TR-WCAP-16406-P.

3. For the pump wear evaluation, debris particles smaller than 50 µm were assumed to cause only erosive wear on the pump internals. This assumption is based on the design running clearances in the ECCS and CSS pumps typically being in the range of 0.010 to 0.025 in. (0.005 in. (127 µm) minimum radial clearance). Debris particles smaller than 50 µm are approximately 40 percent of this radial clearance and, therefore, were considered unlikely to bridge the gap and cause abrasive wear.

4. Debris particles greater than 50 µm are conservatively assumed to cause abrasive wear of the pump internals

The licensee's assumptions are acceptable based on (1) the rationale presented, (2) being conservative, or (3) being based on TR-WCAP-16406-P methods.

The licensee's evaluation concluded that the performance of the ECCS/CSS components would not be affected by the ingested debris. The following is a summary of the evaluation results:

Valves

The ECCS and CSS valves were evaluated for erosive wear and plugging due to debris ingestion. The detailed evaluation of the 24 Sequoyah Unit 1 and Unit 2 ECCS injection flow balancing valves demonstrated that all valves in their evaluated positions can pass all debris for an assumed strainer opening diameter of 0.125 in. or less. All other ECCS and CSS valves have much larger openings and are not subject to plugging. All valves requiring detailed evaluation for sedimentation were found to have a sufficient flow velocity to preclude sedimentation. ECCS valves that are closed prior to exposure to debris-laden fluid do not require an explicit flow calculation. The detailed erosion evaluation performed for each of the 24 ECCS throttle valves demonstrated acceptable 30-day erosion in all cases.

Pumps

Three aspects of pump performance were evaluated for debris ingestion effects. These included hydraulic performance, mechanical shaft seal assembly performance, and mechanical performance (vibration). For the hydraulic performance evaluation, only the RHR and CSS pumps required detailed evaluation. For these pumps, the increased clearances, due to erosive and abrasive debris wear, is calculated to be less than three times the design clearance. Consequently, the hydraulic performance of the pumps is not affected by ingested debris. The mechanical shaft seal assembly performance evaluation confirmed the ability of the Sequoyah 1 and 2 ECCS and CSS pumps to meet the acceptance criteria for backup seal bushing material and non-use of cyclone separators. This aspect of the pump design was concluded to be acceptable.

For the mechanical evaluation, the multistage safety injection and centrifugal charging pumps were evaluated for an increase in the wear ring gap due to erosive, abrasive, and debris packing type wear. The postaccident wear ring stiffness was established for both the pump suction side (abrasive wear) and discharge side (packing wear) and then compared to the minimum stiffness required for successful pump operation. Since the postaccident wear ring stiffness exceeds the required minimum value, pump mechanical performance was concluded to be acceptable.

Heat–Exchangers

Sequoyah ECCS and CSS heat exchangers were evaluated for tube plugging and tube failure due to erosive wear. The heat exchanger tube plugging evaluation confirmed that the inside diameter of all tubes are larger than the debris particle size. Consequently, tube plugging is not expected to occur. For the heat exchanger wear evaluation, the actual tube wall thickness, reduced by the thickness lost to erosion, was found to be greater than the wall thickness required to retain system pressure. As such, tube failure due to erosion is not expected to occur.

Orifices

Flow orifices in the ECCS and CSS system piping were evaluated for plugging and failure due to erosive wear. The orifice plugging evaluation confirmed that all ECCS and CSS orifice bore diameters are larger than the bypassed debris size. Consequently, orifice plugging is not expected to occur. For the orifice wear evaluation, the increase in the orifice inner diameter caused by erosion resulted in a calculated increase in system flow of less than 3 percent. As such, the orifice performance was considered acceptable.

Spray Nozzles

Spray nozzles in the CSS system were evaluated for plugging and failure due to erosive wear. The spray nozzle plugging evaluation confirmed that all CSS spray nozzle diameters are larger than the debris particle size. Consequently, spray nozzle plugging is not expected to occur. For the spray nozzle wear evaluation, the increase in nozzle diameter caused by erosion resulted in an insignificant (less than 10 percent) increase in system flow. As such, nozzle performance was considered acceptable.

Instrumentation

Instruments in the ECCS and CSS systems were evaluated for debris collection in the instrument sensing lines. The instruments of concern were those that are connected to the recirculating flow path throughout the ECCS or CSS systems and which must function postaccident to support application of emergency procedures. For the Sequoyah 1 and 2 instrumentation sensing line evaluation, the transverse ECCS recirculation flow velocity was found to be greater than the minimum velocity for debris settlement (2.94 ft/sec). Consequently, failure of the instrumentation due to debris settlement in the sense lines is not expected to occur. An evaluation was also performed to address potential debris collection in the reactor vessel level instrumentation system (RVLIS). Debris collected in the reactor vessel lower plenum may affect the performance of the RVLIS in measuring reactor vessel water level during recirculation. For the Sequoyah 1 and 2 RVLIS, the reactor vessel water level is measured with a differential pressure transmitter connected to the top and bottom of the reactor vessel. No active circulation will occur in the reactor vessel upper head volume, so no debris will affect the RVLIS upper connection. The low flows in the lower plenum combined with the fact that the RVLIS impulse lines are dead-ended will prevent both the entry of debris into the RVLIS connection and the collection of debris in sufficient quantity to affect the differential pressure transmitter. Therefore, debris settling in the lower plenum of the reactor vessel is not expected to affect the Sequoyah 1 and 2 RVLIS water level measurements.

NRC STAFF CONCLUSION:

The NRC staff reviewed the evaluation results presented in the licensee’s GL 2004-02 response. The licensee performed ex-vessel downstream effects calculations and analyses in accordance with the NRC recognized methods prescribed in TR-WCAP-16406-P-A, Revision 1 and the associated NRC SE, including limitations and conditions. Therefore, the NRC staff concludes that the downstream effects of debris laden recirculated sump fluid on ex-vessel downstream components and systems have been adequately addressed at Sequoyah 1 and 2. The NRC staff considers this item closed for GL 2004-02.

16.0 DOWNSTREAM EFFECTS - FUEL AND VESSEL

The objective of the downstream effects, fuel and vessel section, is to evaluate the effects that debris carried downstream of the containment sump screen and into the reactor vessel has on long-term core cooling.

INITIAL NRC STAFF REVIEW:

The initial staff review is based on documentation provided by the licensee through February 29, 2008.

The licensee’s GL 2004-02 supplemental response contains a detailed description of the methods used by the licensee to evaluate the fuel and vessel downstream effects of debris that bypass the ECCS sump strainers. Generally, the licensee followed the methods of TR-WCAP-16406-P, Revision 1 to evaluate the potential for core inlet and fuel blockage due to debris bypassing the sump strainer and compared the results to the results contained in TR-WCAP-16793-NP, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical debris in the Recirculating Fluid, Revision 0.” For the evaluation of chemical effects in the core region, the licensee compared Sequoyah's sump pool chemistry to the chemistry evaluated in TR-WCAP-16793-NP and concluded that the Sequoyah sump pool chemistry was conservatively enveloped by the WCAP. The licensee did not perform a plant-specific LOCA Deposition Analysis Model LOCADM calculation but stated that it will complete a plant-specific calculation to confirm its conclusion.

Section 9 of TR-WCAP-16406-P, "Evaluation of Downstream Sump Debris Effects in Support of GSI-191," Revision 1, describes a general method for evaluating the potential for debris blockage of reactor internals and fuel during a LOCA following realignment of the ECCS for sump recirculation. However, the NRC SE of TR-WCAP-16406-P does not acknowledge Section 9 of the WCAP as being an acceptable method for in-vessel downstream evaluations and defers the evaluation of in-vessel effects to TR-WCAP-16793-NP.

TR-WCAP-16793-NP, "Evaluation of Long-Term Core Cooling Associated With Sump Debris Effects," Section 7 summarizes the bases for concluding that reasonable assurance of long-term core cooling for all plants is demonstrated. Although some assertions made in the WCAP (related to core blockage) are still under examination, the licensee appears to have demonstrated that core blockage at Sequoyah will not occur and that the core cladding temperature will be maintained below the accepted value of 800 ºF. However, some questions remain as to the adequacy of the fuel deposition analysis. The licensee evaluations are described below:

<u>Core Inlet and Fuel Blockage</u>

Initially, the licensee performed an evaluation of the effects of ingested debris on the Sequoyah fuel and reactor vessel internals using the methods summarized in TR-WCAP-16406-P, Revision 1 as follows:

For the reactor vessel internals, the licensee reviewed the flow paths for cold leg and hot leg recirculation and performed a dimensional analysis to establish the minimum equipment clearances in the flow paths. The dimensional analysis established that all of the essential flow paths through the reactor internals were adequate to preclude plugging by sump debris. The limiting dimensions of the essential flow paths in the upper and lower internals were all greater than the analyzed maximum debris dimension. The maximum debris dimension was defined as two times the sump screen opening size. The Sequoyah containment sump maximum penetration opening is 0.0951 in. in diameter. The smallest clearance identified by the dimensional analysis was 0.50 in. Therefore, the licensee concluded that the ingested debris was sufficiently small to preclude plugging in the vessel internals.

For the evaluation of plugging in the fuel assemblies, the licensee used a simplified version of the method described in TR-WCAP-16406-P. The licensee performed a screening evaluation to determine if sufficient fiber could be collected on the fuel bottom nozzle to form a continuous fiber bed. The logic being that if a continuous fiber bed thicker than 0.125 in. could form across the bottom of the fuel, further evaluation would be required to confirm that that core flow remains adequate with the blockage but if a continuous fiber bed thicker than 0.125 in. could not form across the bottom of the fuel, no further fuel evaluation would be necessary. For the screening review evaluation of the cold-leg break, the licensee concluded that the high rate of bypass flow around the core precludes the formation of a fiber bed since most of the fibrous debris passing through the containment sump screen bypasses the core and is returned to the containment sump for further filtering and therefore the fiber bed builds to a maximum thickness of approximately 0.005 in. in 4 hours. For the evaluation of the hot-leg break, assuming a sump screen capture rate of 95 percent and a fuel capture of 95 percent, the thickness of the fibrous bed formed on the bottom of the fuel was calculated to be 0.075 in.

The licensee stated that because a continuous fiber bed thicker than 0.125 in. was shown not to form across the bottom of the fuel for either cold-leg or hot-leg breaks, adequate cooling flow would be provided to the fuel assemblies.

The licensee compared the results of the above described evaluations to the TR- WCAP-16793-NP evaluations of fuel clad temperature response to blockage at the core inlet and the evaluation of fuel clad temperature response to local blockages or chemical precipitation on fuel clad surfaces. The licensee concluded that the Sequoyah reactor vessel internals and fuel blockage evaluation results obtained through the use of methods described in TR-WCAP-16406-P are bounded by the evaluations in TR-WCAP-16793-NP, without exception.

Chemical Deposition

Section 5.7 of TR-WCAP-16793-NP contains an evaluation of post-LOCA chemical reactions in the reactor core for long-term containment sump recirculation operation using the LOCADM developed by Westinghouse. The WCAP demonstrates that, for the enveloping parameters evaluated, the core cladding temperature does not exceed 324 °F--a temperature well below the maximum NRC accepted temperature limit of 800 °F. The licensee reviewed the evaluation of chemical effects in the core region (including the potential for plate-out on fuel cladding) contained in TR-WCAP-16793-NP and compared the conditions evaluated in TR-WCAP-16793-NP to the chemistry values and operating conditions at Sequoyah. The table below shows the compared parameters.

Parameter	WCAP Sample Calculation Input Condition	Sequoyah Condition
Core Thermal Power Rating	3,185 Mega Watts Thermal (MWt)	3,455MWt
Fiber (Fiberglass) Debris Load	7,000 ft^3	12.5 ft^3
Calcium Silicate Debris Load	80 ft^3	None
Buffer Agent	Sodium Hydroxide	Sodium Tetraborate
Hot-Leg Switchover Time	13 hours	5 hours
Aluminum Surface Area	15,988 ft^2	1,427 ft^2

Based on this comparison, the licensee concluded that the sample calculation in TR-WCAP-16793-NP was conservative with respect to Sequoyah 1 and 2 service conditions and, as such, chemical effects in the Sequoyah 1 and 2 core regions do not compromise long-term core cooling. The licensee stated that a Sequoyah plant-specific LOCADM calculation will be performed to confirm this conclusion.

The licensee based his fuel cladding temperature analysis on the sample LOCADM calculation in TR-WCAP-16793-NP. However, conditions and limitations No. 13 of the NRC staff's SE requires that the aluminum release rates used in the LOCADM spreadsheet be increased by a factor of two for the initial portion of the LOCA. Therefore, the sample calculation contained in Revision 0 of the WCAP may not reflect maximum cladding temperature.

Sequoyah Units 1 and 2 are low-fiber plants. There is no fibrous or Min-K insulation installed in the plant that can transport to the reactor vessel during a LOCA. The quantity of latent fiber and debris, failed coatings, and failed RMI insulation assumed by the licensee is very conservative. A latent debris walkdown assessed the latent debris at 24.5 lb with only a few latent fibers found. However, the licensee assumed 200 lb of latent debris in their analytical assessments and of the 200 lb, 15 percent or 30 lb (12.5 ft^3) of the debris was assumed to be fibrous.

The following RAI was issued in the NRC letter dated November 25, 2008.

RAI 7

> The NRC staff considers in-vessel downstream effects to not be fully addressed at Sequoyah Nuclear Plant (SQN), as well as at other PWRs. The licensee's submittal for SQN refers to the draft Westinghouse topical report, TR-WCAP-16793-NP. The NRC staff has not issued a final SE for TR-WCAP-16793-NP. The licensee may demonstrate that in-vessel downstream effects issues are resolved for SQN by showing that the plant conditions are bounded by the final TR-WCAP-16793-NP and the corresponding final NRC staff SE, and by addressing the conditions and limitations in the final SE. The licensee may also resolve this item by demonstrating without reference to TR-WCAP-16793-NP or the staff SE that in-vessel downstream effects have been addressed at SQN. In any event, the licensee should report how it has addressed the in-vessel downstream effects issue within 90 days of issuance of the final NRC staff SE on TR-WCAP-16793-NP. The NRC staff is developing a regulatory issue summary to inform the industry of the staff's expectations and plans regarding resolution of this remaining aspect of NRC's GSI-191.

By letter dated June 27, 2014, the licensee submitted a final supplemental response to GL 2004-02. In the supplement, the licensee stated that the in-vessel downstream- effects analysis for Sequoyah utilizes the TR-WCAP-16793-NP, Revision 2, methodology and addresses both material deposition on the fuel rods and core blockage due to fibrous debris which could bypass the containment sump strainer.

FINAL NRC STAFF REVIEW

By letter dated June 27, 2014, the licensee submitted the GL 2004-02 in-vessel downstream-effects resolution for Sequoyah, Units 1 and 2. The final NRC staff review is based on the licensee's June 27, 2014, letter.

Evaluation criteria

On April 8, 2013, the NRC staff issued an SE for TR-WCAP-16793-NP, Revision 2, finding it an acceptable model for assessing the effect of sump strainer bypassed fibrous, particulate, and chemical debris on core cooling in PWRs (ADAMS Accession No. ML13084A154). The TR guidance and acceptance bases were developed through analyses and flow testing using representative fuel assemblies and ECCS flow rates. In order to demonstrate adequate core cooling capability, the limitations and conditions section of the NRC SE of the TR, and GL 2004-02 response content guide (ADAMS Accession No. ML073110278) specify certain actions for licensees. These licensee actions for closeout of GL 2004-02 are described herein.

The GL 2004-02 response content guide specified that the response to Item n, “Downstream Effects - Fuel and Vessel,” confirm that the licensee’s evaluation is consistent with, or bounded by, the industry generic guidance contained in TR-WCAP-16793-NP, Revision 2, as modified by the NRC staff’s conditions and limitations stated in the NRC SE on that document. Also, the response shall briefly summarize the application of the WCAP evaluation methods and include the following information:

a) The available driving head and ECCS flow rate used in the evaluation of the hot-leg break LOCA scenario,

b) The type(s) of fuel and inlet filters installed in the plant,

c) The results of the LOCADM calculation, including the predicted peak clad temperature,

d) The amount of fiber (in grams per fuel assembly) that is assumed to reach the core inlet after a LOCA and,

e) The method(s) used to estimate the quantity and size distribution of the fibrous debris that would pass through the ECCS sump strainer and reach the core inlet during a LOCA.

   (Note: The Limitations and Conditions Section of the NRC SE of TR-WCAP-16793-NP, Revision 2, states that licensees may determine the quantity of debris that passes through their strainers by: (1) performing strainer bypass testing using the plant strainer design, plant-specific debris loads, and plant-specific flow velocities; (2) relying on strainer bypass values developed through strainer bypass testing of the same vendor and same perforation size, prorated to the licensee’s plant-specific strainer area; approach velocity; debris types, and debris quantities; or (3) assuming that the entire quantity of fiber transported to the sump strainer passes through the sump strainer. Further, NRC staff review of the Nuclear Energy Institute document, “Clean Plant Acceptance Criteria for Emergency Core Cooling Systems,” as documented in a letter dated May 2, 2012 (ADAMS Accession No. ML120730181), allows an assumption of 75 percent transport and 45 percent fiber pass-through for a typical perforated strainer if a plant can demonstrate that the total in-containment latent fiber plus fibrous insulation located within the ZOI is less than 20 lb.

   When applying the above criteria, the licensee shall ensure that the width of any gaps in the strainer assembly does not exceed the diameter of the strainer perforations and the total area of the gaps does not exceed 1 percent of the total strainer perforation area.

f) A description of any deviations from, or exceptions to the WCAP or the NRC SE of the WCAP.

In the licensee's letter dated June 27, 2014, the following information was provided:

The licensee TVA performed a plant-specific evaluation for Sequoyah using TR-WCAP-16793-NP, Revision 2, and the associated NRC SE of that document. The evaluation results are:

1. The maximum calculated cladding temperature is 384 °F. This is less than the WCAP-recommended maximum cladding temperature of 800 °F.

2. The total deposition thickness is 0.01412 in. (14.12 mils). This is less than the recommended total debris deposition thickness of 0.050 in.

3. Based on Sequoyah-specific strainer bypass testing, the fiber calculated to bypass the strainers and reach the fuel assembly is 14.8 grams per fuel assembly. This quantity is less than the TR-WCAP-16793-NP acceptance criteria of 15 grams per fuel assembly.

Also, in the letter dated June 27, 2014, the licensee satisfactorily demonstrated compliance with the 14 Limitations and Conditions of the NRC SE of TR-WCAP-16793-NP-A, Revision 2.

Based on the above information, the licensee concluded that Sequoyah, Units 1 and 2, meet the guidance specified in TR-WCAP-16793-NP, Revision 2, and the specifications, limitations, and conditions listed in the associated NRC SE. Therefore, Sequoyah, Units 1 and 2, meet the requested actions specified in GL 2004-02.

NRC STAFF FINAL CONCLUSION

The NRC staff reviewed the description of the analyses, strainer bypass testing, and compliance with the Limitations and Conditions of the SE, as described in the licensee's GL 2004-02 response to item n and find that the licensee response addressing in-vessel downstream-effects for Sequoyah, Units 1 and Unit 2, satisfies the requirements stated in TR-WCAP-16793-NP-A, Revision 2, and the NRC SE of that document. Therefore, the NRC staff concludes that the licensee has adequately addressed the potential effects of ECCS sump strainer-bypassed debris on core cooling at Sequoyah, Units 1 and 2. The NRC staff considers this item closed for GL 2004-02.

17.0 CHEMICAL EFFECTS:

The objective of the chemical effects section is to evaluate the effect that chemical precipitates have on head loss and core cooling.

Since the licensee proposes closure of GL 2004-02 with a simplified chemical effects criterion, a detailed evaluation is not required provided that sufficient bare strainer area is demonstrated. Previous testing as shown in NUREG/CR-6913 "Chemical Effects Head Loss Research in Support of Generic Safety Issue 191" (not publicly available) validated that chemical precipitates are expected to pass through a bare strainer. Therefore, the simplified chemical effects evaluation should demonstrate for the maximum debris generation/transport break that the screen design provides to allow chemical precipitates to pass unimpeded for sufficient bare strainer area.

INITIAL NRC STAFF REVIEW:

The initial staff review is based on documentation provided by the licensee through February 29, 2008.

The licensee initially approached the simplified chemical effects evaluation by comparing the NRC and nuclear industry's jointly sponsored Integrated Chemical Effects Test (ICET) program Test 5 and the Sequoyah 1 and 2 plant specific parameters. The evaluation concluded that the critical parameters in the ICET program Test 5 bound the plant parameters. Wherein, the licensee would account for chemical effects margin by addition of area requirements to the strainer.

The NRC staff had initial concerns with the overall strategy to evaluate potential chemical effects. The following questions with the licensee's evaluation were identified during the initial review:

- More information is needed from the licensees overall strategy to evaluate potential chemical effects including demonstrating that, with chemical effects considered, there is sufficient NPSH margin available during the ECCS mission time.

- Additional information is needed with regards to licensees existing chemicals. The licensee needs to identify, if applicable, any plans to remove certain materials from the containment building and/or to make a change from the existing chemicals that buffer containment pool pH following a LOCA.

- If bench-top testing is being used to inform plant specific head loss testing, indicate how the bench-top test parameters (e.g., buffering agent concentrations, pH, materials, etc.) compare to your plant conditions. The NRC staff needs more information addressing uncertainties related to head loss from chemical effects including, but not limited to, use of chemical surrogates, scaling of sample size and test durations. Also, the licensee needs to address basis for determining that allowances made for chemical effects are conservative.

INITIAL NRC STAFF CONCLUSION:

For this review the licensee has not provided information such that the NRC staff has reasonable assurance that the subject review area has been overall addressed conservatively or prototypically. The NRC staff's main concern is that the licensee did not provide enough justification needed for a simplified chemical effects evaluation. Justification for this simplified approach should be addressed by providing the amount of debris to reach the strainer, the amount of bare strainer area and how it was determined, and any additional information that is needed to show why a more detailed chemical effects analysis is not needed. For that reason the NRC staff issued the following RAI letter dated October 14, 2009.

RAI 9

The February 2009 SQN supplemental response concludes that detailed chemical effects evaluations are not necessary due to the lack of a fiber bed on the strainer surface. The staff accepts that maintaining sufficient bare strainer area will mitigate potential chemical effects on the sump strainer. Staff guidance provided in a March 28, 2008, letter (ADAMS Accession No. ML080380214) states, “Plants that plan to credit bare strainer area and perform a simplified chemical effect evaluation should demonstrate, for the maximum debris generation/transport break that the screen design allows for chemical precipitates to pass unimpeded due to the excess available bare strainer area. For the purpose of this simplified analysis, strainer area with a very thin layer of debris that covers the strainer flow area is considered to be different from bare strainer area.” However, the bare strainer argument is contingent on NRC staff agreeing that a filtering fiber bed will not form on the entire strainer surface and the staff has not agreed that a filtering bed will not form for SQN. Therefore, unless the NRC staff is able to accept the maintenance of sufficient bare strainer area through the RAI resolution process, please address chemical effects on an alternate basis.

RAI 9 LICENSEE RESPONSE:

A conservative thin bed formation test was performed using the “test tank” protocol. The test evaluated a beyond design-basis fiber debris load of sufficient volume to determine if a uniform fiber bed would form on the strainer surface. The results of the thin bed test established that a thin bed did not form for the tested conditions. Based on these results, a detailed chemical effects evaluation was not performed.

FINAL NRC STAFF EVALUATION:

The final NRC staff review is based on the licensee’s RAI responses and supplemental information through June 27, 2014.

RAI 9 NRC STAFF EVALUATION:

In the licensee’s response to RAI 9, the licensee demonstrated sufficient bare strainer area with their simplified chemical effects evaluation. The licensee’s simplified chemical effects evaluation established that during maximum debris generation/transport break, the screen design would allow chemical precipitates to pass unimpeded due to the excess of available bare strainer area. Their approach was justified by their assumed design-basis debris load, the amount of debris to reach the strainer, the amount of bare strainer area and how it was determined. The licensee stated that their design-basis debris load is 15 lb (6.25 ft^3) and their design strainer area is 1,409 ft^2 after accounting for sacrificial area. This results in a potential theoretical bed thickness of 0.053 in.; which is less than 0.0625 in., as required to achieve resolution of GL 2004-02, with the clean plant criteria.

Moreover, the licensee stated that they had performed a conservative design-basis debris loaded thin bed test. The test was designed to determine whether a thin bed could occur on the strainer and to determine the head loss resulting from the design-basis debris load. The licensee described the methods used to perform the test and included the test report. The test resulted in a debris head loss of about 2.5 ft, head loss occurred when the fiber was added to the test and no significant increase in head loss occurred when chemicals were added. At the end of the test it was observed that the strainer was not covered with a uniform thin bed.

The NRC evaluated the licensee's response to RAI 9, found the thin bed test was performed in accordance with NRC staff guidance for strainer head loss testing. The test showed that the strainer can accommodate the assumed fibrous debris load (15 lb) for the strainer without excessive head loss or even developing a full filtering bed. The NRC staff finds that the strainer can accommodate the design-basis debris load without forming a full filtering debris bed.

Therefore the response to RAI 9 is acceptable and the NRC staff accepts the simplified chemical effects analysis since the licensee demonstrated that a filtering bed would not form on the entire Sequoyah 1 and 2 strainers.

FINAL NRC STAFF CONCLUSION:

For this review area, based on the results provided by the licensee, the NRC staff concludes that the chemical effects portion of the analysis has been completed adequately. This conclusion is based on the licensee demonstrating that the Sequoyah fiber source term will not result in a filtering bed over the entire sump strainer area. In addition, a test that included the design-basis fiber and particulate loads, and chemical precipitates resulted in acceptable head loss. This provides additional assurance that the evaluation is acceptable.

For this review area, the licensee has provided information such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. The licensee has provided information such that the reviewer has high confidence in the adequacy of the licensee's test and evaluation methods in this subject area.

Based on the above NRC staff review, the NRC staff concludes that the Sequoyah chemical effects evaluation is acceptable. Therefore, the NRC staff considers this item closed for GL 2004-02.

18.0 LICENSING BASIS

The objective of the licensing basis section is to provide information regarding any changes to the plant licensing basis due to the changes associated with GL 2004-02.

The licensee committed to change the Updated Final Safety Analysis Report (UFSAR) in accordance with 10 CFR 50.71(e) to reflect the changes to the plant in support of the resolution to GL 2004-02. In addition, the licensee stated that changes would be made to the UFSAR describing the new licensing basis to reflect the revised debris loading as it affects ECCS sump strainer performance and in-vessel effects, including the following:

- Break Selection
- Debris Generation
- Latent Debris
- Debris Transport
- Head Loss
- Additional Design Considerations

NRC STAFF CONCLUSION:

For this review area the licensee has provided information, such that the NRC staff has reasonable assurance that the subject review area has overall been addressed conservatively or prototypically. Based on the licensee's commitment, the NRC has confidence that the licensee will affect the appropriate changes to the Sequoyah Unit 1 and 2 UFSAR, in accordance with 10 CFR 50.71(e), that will reflect the changes to the licensing basis as a result of corrective actions made to address GL 2004-02. Therefore, the NRC considers this item closed for GL 2004-02.

19.0 CONCLUSION

The NRC staff has performed a thorough review of all licensee's responses and RAI supplements to GL 2004-02. The NRC staff conclusions are documented above. Based on the above evaluations the NRC staff finds the licensee has provided adequate information as requested by GL 2004-02.

The stated purpose of GL 2004-02 was focused on demonstrating compliance with 10 CFR 50.46. Specifically the GL requested addressees to perform an evaluation of the ECCS and CSS recirculation and, if necessary, take additional action to ensure system function in light of the potential for debris to adversely affect long-term core cooling. The NRC staff finds the information provided by the licensee demonstrates that debris will not inhibit the ECCS or CSS performance of its intended function in accordance 10 CFR 50.46 to assure adequate long-term core cooling following a design-basis accident.

Therefore, the NRC staff finds the licensee's responses to GL 2004-04 are adequate and considers GL 2004-02 closed for the Sequoyah Nuclear Plant, Units 1 and 2.