Southern Nuclear

Justin T. Wheat
Nuclear Licensing Manager

40 Inverness Center Parkway
Post Office Box 1295
Birmingham, AL 35242
205 992 5998 tel
205 992 7601 fax

jtwheat@southernco.com

FEB 1 2 2018

Docket Nos.: 50-424
50-425

NL-18-0086

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D. C. 20555-0001

Vogtle Electric Generating Plant – Units 1&2
Systematic Risk-Informed Assessment of Debris Technical Report SNC Response to NRC Request for Additional Information (RAIs #16-36)

Ladies and Gentlemen:

By letter dated April 21, 2017 (Agencywide Documents Access and Management System Accession No. ML17116A098) as supplemented by letter dated July 11, 2017 (ADAMS Accession No. ML17192A245), Southern Nuclear Operating Company, Inc. (SNC) submitted a plant-specific technical report for Vogtle Electric Generating Plant (VEGP), Units 1 and 2 and requested U.S. Nuclear Regulatory Commission (NRC) approval of the methods and inputs described in the technical report. The plant-specific technical report describes a risk-informed methodology to evaluate debris effects with the exception of in-vessel fiber limits. This technical report addresses Generic Safety Issue 191 (GSI-191) and Generic Letter 2004-02. By letter dated January 11, 2018, the NRC staff notified SNC that additional information is needed for the staff to complete their review. The Enclosure provides the SNC response to the NRC requests for additional information for RAIs 16-36. SNC provided responses for RAIs 1-14 by letters dated November 9, 2017; January 2, 2018; and January 9, 2018. RAI 15 is being answered through a separate application as requested by NRC staff by letter dated January 1, 2018 (ADAMS Accession No. ML17354A782).

This letter contains no NRC commitments. If you have any questions, please contact Ken McElroy at 205.992.7369.

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NRR

I declare under penalty of perjury that the foregoing is true and correct. Executed on the 9th day of February 2018.

Respectfully submitted,

Justin T. Wheat
Nuclear Licensing Manager
Southern Nuclear Operating Company

JTW/PDB/SCM

Enclosure: SNC Response to NRC Request for Additional Information (RAIs)

cc: Regional Administrator, Region II
NRR Project Manager – Vogtle 1 & 2
Senior Resident Inspector – Vogtle 1 & 2
State of Georgia Environmental Protection Division
RType: CVC7000

Vogtle Electric Generating Plant - Units 1 & 2
Systematic Risk-Informed Assessment of Debris Technical Report SNC Response to NRC Request for Additional Information (RAIs #16-36)

Enclosure

SNC Response to NRC Request for Additional Information

NRC RAI 16

Enclosure 3, Section 9.0 states that debris is assumed to arrive at the strainers as a function of pool turnover time that changes the relative accumulation of debris on strainers, depending on the operating alignments and run time of pumps taking suction from the pool. Section 10.1 states that head losses are applied using a rule-based approach based on the amount of fiber on the strainer. Please confirm that head loss is applied at each time step as follows:

a. If there is any debris on the strainer, but it is less than 0.45 inches theoretical thickness, the thin bed head loss is applied.

b. If the debris bed has a theoretical thickness of greater than 0.45 inches, the calcium phosphate head loss is added to the total.

c. If the debris bed is greater than 32.04 cubic feet (0.57 inches) per residual heat removal (RHR) strainer, the full load head loss is applied in place of the thin bed head loss, and appropriate chemical effects adders are applied.

d. If the amount of aluminum in solution reaches the calculated saturation limit or at 24 hours, whichever occurs first, the sodium aluminum silicate head loss is added to the total.

e. The extrapolation value is added to the head loss at 7.5 hours.

f. The head loss is corrected for flow and temperature (difference from test flow velocity and temperature) at each time step. The head loss correction used is the greater of that derived from the thin bed or full load test for the conditions that exist at the time step being evaluated.

g. When there is flow through the strainer, the clean strainer head loss is added at every time step.

Please confirm that this description of the head loss model is correct. If the description is not correct, please provide a revised description, including a graphical representation of the head loss response to changes in the various model parameters.

SNC Response to RAI 16

The description above is accurate. However, it should be noted that the volume of debris required to transition from the thin bed head loss to the full load head loss (see Part c above) is dependent on the effective strainer area. The strainer area is adjusted to account for the contribution of miscellaneous debris [Ref. 1, p. E3-20] and brief periods of time when the strainer is not fully submerged for some reactor cavity breaks [Ref. 1, p. E3-18]. Therefore, the debris volume required to form a 0.57-inch thick

bed is scaled down based on the reduced strainer surface area, and the full load test head loss is applied for a fiber debris quantity less than 32.04 ft^3.

Figure 16-1 illustrates the time-dependent changes in head loss and NPSH margin for a specific break based on the methodology described above.

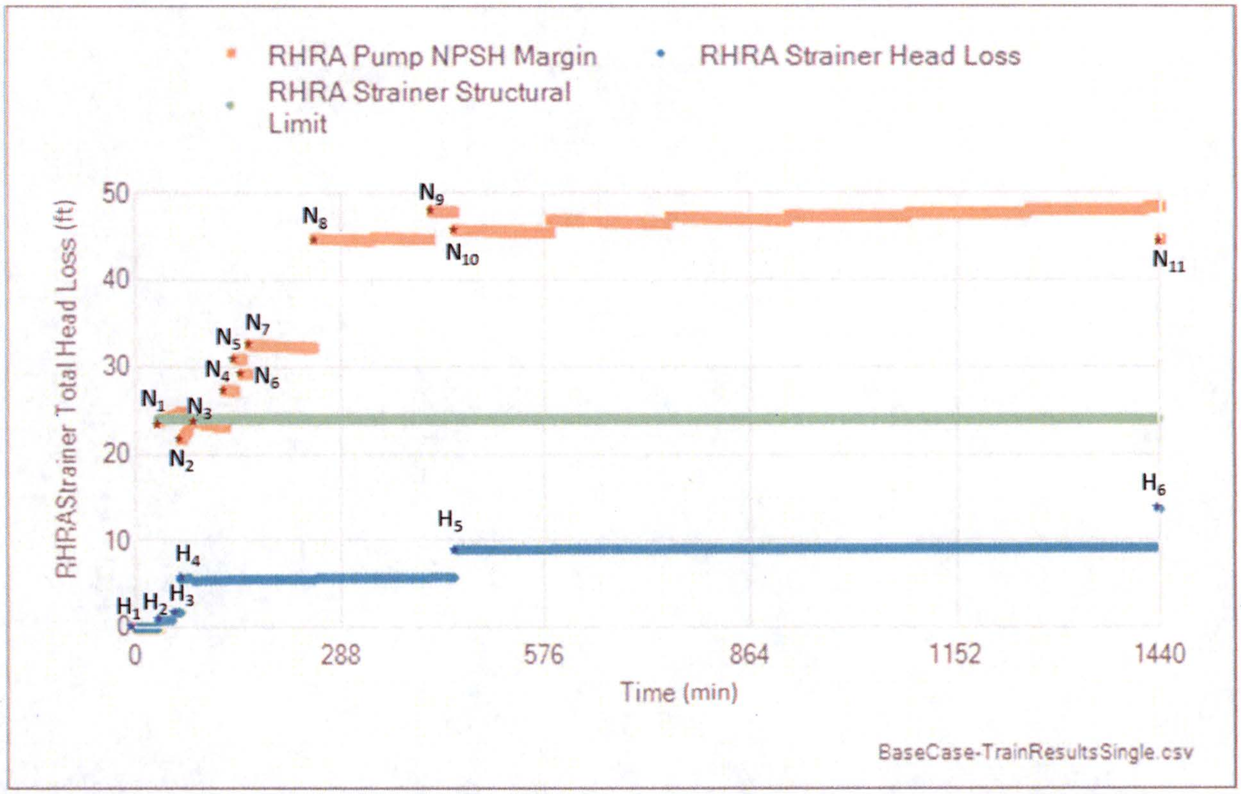

Figure 16-1: Head Loss across the RHRA Strainer (Weld 11201-003-5-RB, 19-inch partial break)

The following significant changes in head loss are noted:

- H_1: There is no strainer head loss when the RHR pumps are drawing from the refueling water storage tank (RWST).
- H_2: When the RHR pumps switch over to sump recirculation, the clean strainer head loss is applied [Ref. 1, p. E5-81]. Also, with the initial arrival of debris on the strainer, the conventional debris head loss from the thin-bed test is added [Ref. 1, p. E5-82] and corrected for the pool temperature and strainer approach velocity [Ref. 1, pp. E5-77 to E5-80].
- H_3: As debris continues to accumulate on the strainer and the bed thickness exceeds 0.45 inches, the calcium phosphate head loss is applied [Ref. 1, p. E5-82] and corrected for the pool temperature and strainer approach velocity [Ref. 1, pp. E5-77 to E5-80].
- H_4: When the fiber debris load on the strainer exceeds the quantity tested in the thin-bed test, the conventional head loss is changed from the thin-bed test to the full load test [Ref. 1, p. E5-82] and corrected for the pool temperature and strainer approach velocity [Ref. 1, pp. E5-77 to E5-80].

- H_5: At 7.5 hours following the start of the event, the 30-day head loss extrapolation constant is added to the total head loss [Ref. 1, pp. E5-80 to E5-81] and corrected for the pool temperature and strainer approach velocity [Ref. 1, pp. E5-77 to E5-80].
- H_6: At 24 hours following the start of the event, aluminum precipitation is forced [Ref. 1, p. E5-153]. At this point, the sodium aluminum silicate head loss is applied [Ref. 1, p. E5-82] and corrected for the pool temperature and strainer approach velocity [Ref. 1, pp. E5-77 to E5-80].

Note that there are several fluctuations in the RHR pump net positive suction head (NPSH) margin over the course of the event as shown in Figure 16-1. The following significant changes in NPSH margin are noted:

- N_1: The RHR pump NPSH margin is first calculated and reported when recirculation is initiated. The NPSH margin is increasing due to the increasing water level at this time (the CS pump is still drawing from the RWST).
- N_2: When the head loss increases due to the full load conventional head loss (see H_4 discussion), degasification occurs and the void fraction results in an increase in pump NPSH required and a decrease in the NPSH margin. However, the continued increase in water level simultaneously increases the static head for the NPSH available and reduces the gas void fraction (and corresponding NPSH required), which causes the NPSH margin to increase rapidly.
- N_3: Following switchover of the CS pump to recirculation, the pool water level slowly drops as the reactor cavity fills [Ref. 1, p. E3-18], which results in a decrease in NPSH margin.
- N_4: The NPSH margin increases significantly when the pool temperature drops below 210.96°F (the saturation temperature corresponding to an assumed containment pressure of -0.3 psig) [Ref. 1, p. E3-19].
- N_5: Since containment pressure never drops below -0.3 psig, the NPSH margin continues to increase with every subsequent step change in the design basis pool temperature profile.
- N_6: As discussed in the response to RAI 11 Part a [Ref. 2, pp. E-2 to E-3], the NARWHAL model was recently modified to only credit additional accident pressure for the first 2.5 hours (150 minutes) for degasification and flashing calculations (rather than crediting it for the duration of the event). When this additional accident pressure is no longer credited, there is an increase in the gas void fraction, which reduces the NPSH margin.
- N_7: NPSH margin continues to increase with step changes in the design basis pool temperature profile.
- N_8: Another relatively large step change in the pool temperature profile results in a large increase in NPSH margin. Note that the gas void fraction also decreases with decreasing temperature, which contributes to the positive effect on NPSH margin.
- N_9: NPSH margin continues to increase with step changes in the design basis pool temperature profile.
- N_{10}: The increase in head loss due to adding the extrapolation constant (see H_5 discussion) results in a larger void fraction and a decrease in NPSH margin. Following this point, NPSH margin slowly declines for a period of time as a function of the reactor cavity continuing to fill, but continues to increase with each step change in the pool temperature profile.

- N_{11}: The increase in head loss due to adding the aluminum precipitate head loss (see H_6 discussion) results in a larger void fraction and a decrease in NPSH margin.

NRC RAI 17

Enclosure 3, Table 3-9 indicates that a 12.814 inch break results in a failure. This location produces and transports less fiber than other locations that do not fail. Please explain why this debris generation location with less fiber transported results in a failure.

SNC Response to RAI 17

The specific break that is referred to in the RAI is a break on Weld 11201-053-1-RB [Ref. 1, p. E3-43]. This particular break did not exceed the fiber debris limit, but did result in a failure because it exceeded the calcium phosphate debris limit. As shown in Table 3-9 in the submittal, there are some breaks that transport more debris to the strainer without failing [Ref. 1, pp. E3-42 to E3-43]. These breaks generate more transportable fiber debris (fines and small pieces), but less total fiber debris than the break on Weld 11201-053-1-RB. The total quantity of fiber debris (including large and intact pieces) was used to calculate calcium release, which resulted in a larger total calcium phosphate debris load for Weld 11201-053-1-RB compared to the breaks that did not fail.

NRC RAI 18

In Enclosure 5, Section 3.a.1 the licensee states that pipe welds were used as the location of debris generation locations. Please describe how the potential for the failure of piping at locations other than welds (e.g., highly stressed locations, branch connections, and elbows) was considered. If the potential for the failure of piping at locations other than welds was not considered, please provide a basis for not considering locations other than welds.

SNC Response to RAI 18

The potential effects of LOCAs on non-pipe components are addressed in Section 3.2 of Enclosure 1 [Ref. 1, pp. E1-16 to E1-17]. Branch locations and elbows on pipes typically have welds, and so these potential break locations were considered in the evaluation.

It is possible for a break to occur on a segment of pipe between welds, and the guidance in NEI 04-07 suggests analyzing potential breaks at equal increments along the pipe [Ref. 3, p. 3-9]. However, per the NRC's safety evaluation (SE), evaluating breaks at equal increments is "only a reminder to be systematic and thorough" [Ref. 4 p. 17]. The use of Class 1 ISI welds as break locations is both systematic and thorough because there are multiple ISI welds on every pipe in the reactor coolant system (RCS) and the welds cover the range of possible break locations as shown in Figure 3.a.1-1 in Enclosure 5 [Ref. 1, p. E5-12]. In addition, a weld is generally closer to equipment that has a large quantity of insulation, compared to a span of straight pipe (e.g., a break on the hot leg weld at the base of the steam generator will typically generate more debris than a break halfway between the steam generator and reactor vessel). Also, "welds are almost universally recognized as likely failure locations

because they can have relatively high residual stress, are preferentially-attacked by many degradation mechanisms, and are most likely to have preexisting fabrication defects" [Ref. 5 p. xviii].

Since the LOCA frequency was allocated to the individual break locations using the top-down approach as described in Section 3.2 of Enclosure 1 [Ref. 1, p. E1-16], the total plant-wide LOCA frequency is preserved and would not change with the incorporation of additional break locations. The only difference would be that the current breaks postulated on welds would be allocated a smaller portion of the LOCA frequency (in order to allocate some frequency to non-weld locations). Therefore, since non-weld locations do not change the overall LOCA frequency and would not tend to have preferentially more debris than breaks on weld locations, analyzing breaks at these locations would not significantly change the results of the evaluation.

NRC RAI 19

> In Enclosure 1, Section 5.3 is a list of hazards, initiating events, and plant operating modes that were included in the evaluation of debris effects. In this section, the licensee states that initiating events and plant modes that have low potential for any significant risk impact were not evaluated explicitly. Please explain whether breaks postulated to occur outside the first isolation valve are in sections of piping that are normally isolated from the reactor coolant system (RCS) and confirm that the failures of these pipes would not result in RCS leakage rates greater than normal makeup capabilities.

SNC Response to RAI 19

Most of the breaks that are postulated to occur outside the first isolation valve are in sections of piping that are normally isolated from the RCS (e.g., the safety injection system lines that are isolated by check valves). The charging system has flow into the RCS during normal operation with check valves that will close if a break occurs on a weld in this piping. The letdown system piping also has valves that are normally open during operation, but would automatically close upon receipt of a pressurizer low level signal.

Normally closed valves can leak and it is possible for the leakage rates to be greater than normal makeup capabilities. It is also possible for normally closed valves to spuriously open or normally opened valves to fail to close. However, as described in Enclosure 1 Section 5.3, there is no significant difference between the type and quantity of debris generated for breaks outside the first isolation valve compared to breaks inside the first isolation valve [Ref. 1, p. E1-20]. The largest diameter weld outside the first isolation valve is 10.5 inches. A 12-inch break was the smallest break that failed inside the first isolation valve for any of the base case equipment configurations evaluated. Therefore, since there is no significant difference between the types and quantities of debris generated for breaks outside the first isolation valve, it is not likely that any of those breaks would fail due to the effects of debris. Also, even if there were any GSI-191 failures for those breaks, the risk contribution would be negligibly small due to the low likelihood of an isolation valve failing to close, spuriously opening, or developing a large leak. Based on the 2015 update to the NUREG/CR-6928 component failures rates [Ref. 6; 7], the probability of a normally open valve failing to close is less than 4E-04, and the probability of a large leak

or spurious operation of an isolation valve is on the order of 1E-07 or less [Ref. 7 pp. 9, 12, 28]. Therefore, the conditional failure probabilities for breaks outside the first isolation valve would be orders of magnitude smaller than the conditional failure probabilities for equivalent breaks inside the first isolation valve.

NRC RAI 20

The licensee describes the flow model and debris mass balance approach in Section 3.e of Enclosure 5. In Section 13.1 of Enclosure 3, the licensee describes the implementation of the flow model and mass balance approach in the NARWHAL software. The NARWHAL flow model and the debris mass balance approach (i.e., algorithm for distributing debris on strainers, pool, core, and debris retained on structures or not transported to strainers) is not described in sufficient detail (e.g., the use of pool debris transport fractions derived from the computational fluid dynamics (CFD) model) regarding the factors leading to strainer failure. Tables 3.e.6-7 through 3.e.6-14 are stated to be overall transport fractions for various pump operating states and break locations. These tables sometimes have different amounts being transported to each pump, but the staff understands that the debris is allocated to each pump based on its flow rate. Please describe how RHR pumps with the same flow rate appear to accumulate different amounts of debris. Please clarify how the transport values are calculated in NARWHAL. In particular,

a. Please provide a simplified high-level description of the NARWHAL debris transport and distribution models, including a description of how the debris transport fractions from the CFD model, blowdown analysis, and other portions of the transport analysis are incorporated into the final transport values for debris to each strainer. Please describe of which values are inputs to the transport logic trees, which tables are outputs of the transport logic trees, and how the "overall" transport values are treated based on the pump operating states.

b. Is some of the small and large debris predicted to transport to the strainer actually fine debris that was eroded from the small and large pieces of debris?

c. Please provide a description of the methodology used within NARWHAL that keeps track of the fine debris that originates from small and large pieces of debris so that strainer failures are tracked accurately in terms of debris accumulation.

SNC Response to RAI 20

The debris transport fractions shown in Tables 3.e.6-7 through 3.e.6-14 in Enclosure 5 [Ref. 1, pp. E5-51 to E5-54] are total transport fractions that were hand calculated using logic trees with the appropriate blowdown, washdown, pool fill, recirculation, and erosion fractions in the Vogtle debris transport calculation. In this calculation, the recirculation transport fractions were determined using the results from computational fluid dynamics (CFD) simulations. Because the strainers are in different physical locations, the bulk pool velocity varies significantly in the vicinity of each strainer, which

ultimately affects the small and large fiberglass debris transport fractions to each strainer. This is the reason for the differences in the transport fractions for small and large pieces to each of the strainers as reflected in the recirculation transport fractions shown in Enclosure 5 Tables 3.e.6-4 through 3.e.6-6, as well as the overall transport fractions shown in Tables 3.e.6-7 through 3.e.6-14 [Ref. 1, pp. E5-48 to E5-54]. As shown in the example below, the total recirculation transport fraction (sum of the recirculation transport to each strainer) was used to calculate the "sump transportable" debris. To account for time-dependent accumulation, NARWHAL models the sump transportable debris in a simplified manner where it moves with the flow of water, and therefore accumulates proportional to the strainer flow split. The conservatism associated with this simplification was discussed in response to RAI 13 [Ref. 2].

a. In NARWHAL, the fraction of debris that transports to various compartments and strainers is calculated based on user-defined blowdown, washdown, pool fill, and recirculation transport fractions. As shown in Figure 20-1, NARWHAL contains a set group of compartment objects. Since the representation of compartments is fixed, the locations where debris is distributed at the beginning of the event can be calculated with a generic set of equations.

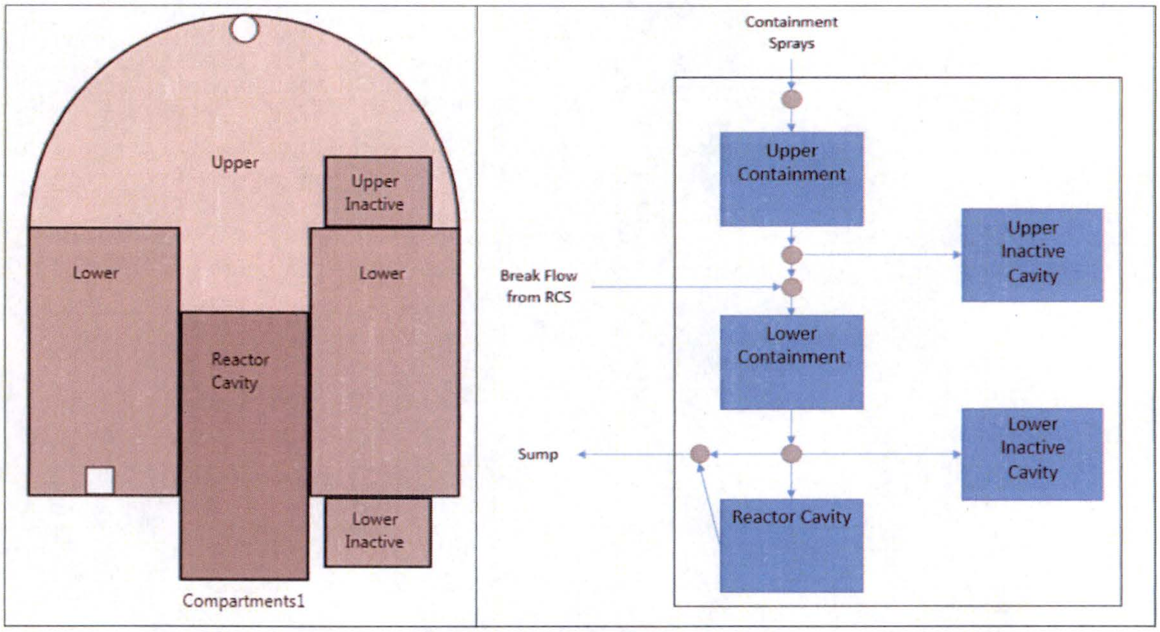

Figure 20-1: NARWHAL connection between compartment objects

The Vogtle blowdown, washdown, pool fill, and recirculation transport fractions are shown in Enclosure 5 Tables 3.e.6-1 through 3.e.6-6 [Ref. 1, pp. E5-46 to E5-50]. Note that the total recirculation transport fraction (i.e., the sum of the recirculation transport fraction to each strainer) is used in NARWHAL. The inputs to NARWHAL include the following transport fractions for each type and size of debris, which are illustrated in Figure 20-2:

- Blowdown tables
  - Upper containment (B_1)
  - Lower containment (B_2)

- Remains in compartment (B_3), where the compartment for each break is defined in the break database
- Washdown tables
  - Annulus (W_1)
  - Steam generator compartment (W_2)
  - Refueling canal drain (W_3)
- Pool fill tables
  - Inactive cavities (P_1)
  - Reactor cavity (P_2)
  - Strainers 1...N ($P_3 \ldots P_N$)
- Recirculation tables
  - Debris in lower containment at end of blowdown (R_1)
  - Debris washed to annulus (R_2)
  - Debris washed to steam generator compartment (R_3)
  - Debris washed to refueling canal drain (R_4)

Note that the washdown fraction applied to the debris remaining in the compartment (B_3) is dependent on where the compartment is located. If the compartment is in the annulus, the Annulus washdown fraction will be applied (W_1). For all other compartments, the Steam Generator washdown fraction (W_2) is applied.

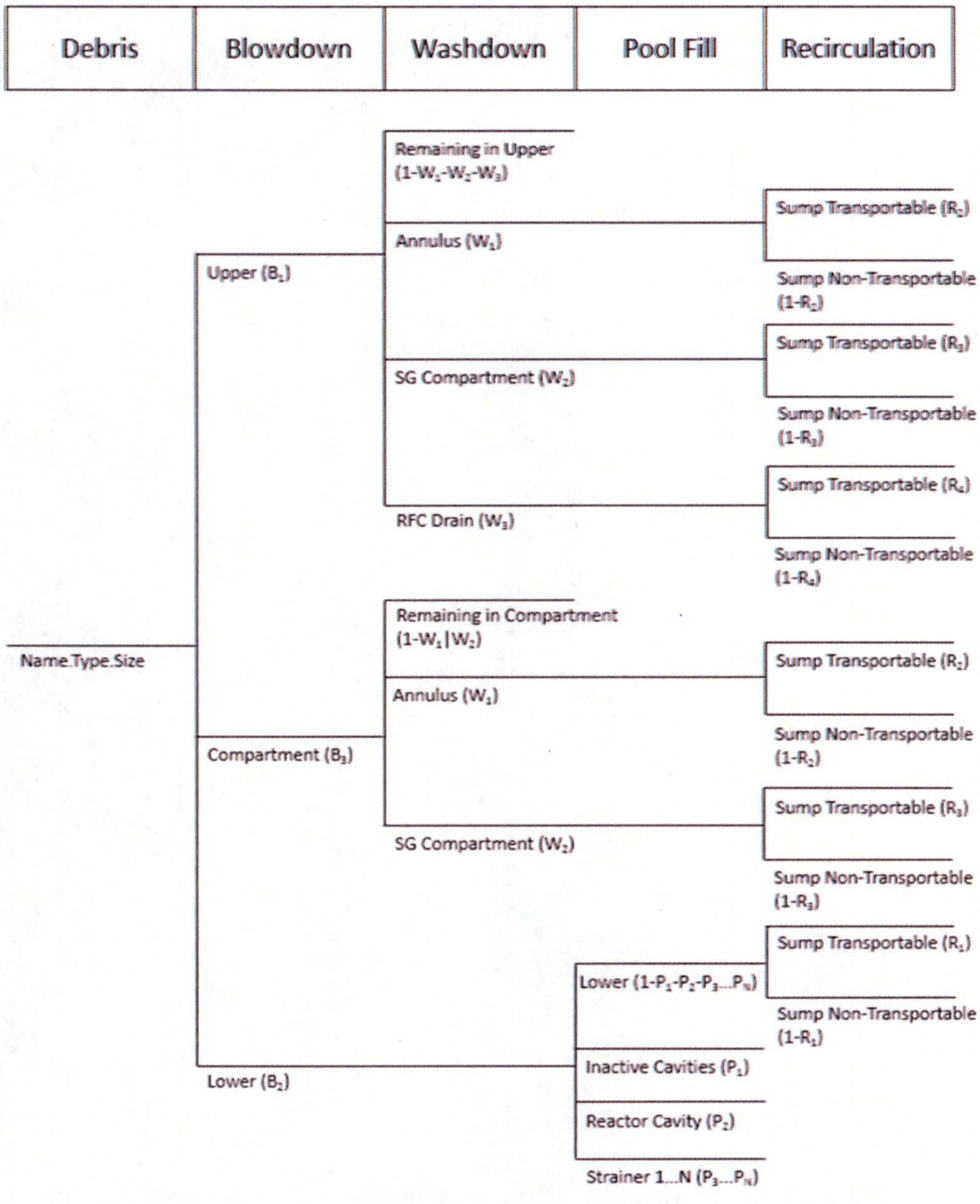

Figure 20-2: NARWHAL debris transport logic tree

Note that debris that is not inside the break zone of influence (ZOI) will transport during washdown, pool fill, and/or recirculation based on the location of the debris. For example, the washdown transport fractions (W_1, W_2, and W_3) would be applicable for unqualified coatings that are defined to be in upper containment. Also, the pool fill transport fractions (P_1, P_2, $P_3 \ldots P_N$) would be applicable for latent debris that is defined to be in lower containment.

Debris that transports to the strainer during pool fill would have a fraction that is captured on the strainer and a fraction that passes through the strainer to the sump cavity. This is based on the type and size of debris as well as the penetration inputs.

Small and large pieces of fiber and particulate debris are also subject to erosion based on the containment spray and pool erosion fractions. Unjacketed pieces of debris held up in upper containment or lower containment will be subject to containment spray erosion, and unjacketed pieces of debris in the sump or on the strainers will be subject to pool erosion. The erosion fraction is multiplied by the debris quantity to determine the quantity of debris that changes size from small/large pieces to fines. The debris in the sump, on the strainers, and in the sump cavity is determined based on the tree in Figure 20-2, and the erosion is then applied. The same process is applied for the debris in upper containment exposed to containment sprays. Also, any debris in upper containment that is eroded to fines is assumed to transport to the sump.

Prior to the start of recirculation, all debris is distributed to upper containment, lower containment, the sump (either transportable or non-transportable), the strainers, and the sump cavities. After erosion is applied, the debris remaining in upper containment and the non-transportable debris in the sump only contributes to chemical effects. Transportable debris in the sump is assumed to be uniformly distributed in the sump volume and will transport to each active strainer as a function of the sump volume and strainer flow split.

For a 29-inch hot leg double ended guillotine break (DEGB) in steam generator compartment Loop 4 at Vogtle with two train operation and sprays activated (corresponding to CFD Case 7 as described in more detail in the response to RAI 26), the following transport fractions were applied for small pieces of fiberglass:

- Blowdown [Ref. 1, p. E5-46]
    - $B_1 = 0.39$
    - $B_2 = 0.61$
    - $B_3 = 0.00$
- Washdown [Ref. 1, p. E5-47]
    - $W_1 = 0.43$
    - $W_2 = 0.37$
    - $W_3 = 0.10$
- Pool fill [Ref. 1, p. E5-47]
    - $P_1 = 0.02$
    - $P_2 = 0.00$
    - $P_3 = 0.0075$
    - $P_4 = 0.0075$
    - $P_5 = 0.0075$
    - $P_6 = 0.0075$
- Recirculation (sum of recirculation transport to all strainers) [Ref. 1, p. E5-49]
    - $R_1 = R_{1,CSA} + R_{1,RHRA} + R_{1,CSB} + R_{1,RHRB} = 0.20+0.00+0.08+0.26 = 0.54$
    - $R_2 = R_{2,CSA} + R_{2,RHRA} + R_{2,CSB} + R_{2,RHRB} = 0.25+0.10+0.06+0.20 = 0.61$
    - $R_3 = R_{3,CSA} + R_{3,RHRA} + R_{3,CSB} + R_{3,RHRB} = 0.17+0.00+0.09+0.25 = 0.51$
    - $R_4 = R_{4,CSA} + R_{4,RHRA} + R_{4,CSB} + R_{4,RHRB} = 0.00+0.00+1.00+0.00 = 1.00$

As shown in Figure 20-3, the small pieces of fiberglass for this example break would be distributed prior to the start of recirculation with approximately 4% retained in upper containment, 53% in transportable regions of the sump, 40% in non-transportable regions of the sump, 1% in inactive cavities, and 0.5% at each of the strainers. The spray and pool erosion and pool fill penetration fractions are also applied at this point. When recirculation is initiated, sump transportable debris would begin to transport to the active strainers based on the sump pool volume (which affects the concentration of debris in the pool) and strainer flow rates (which affects how quickly debris accumulates on the strainers and the relatively accumulation on each strainer).

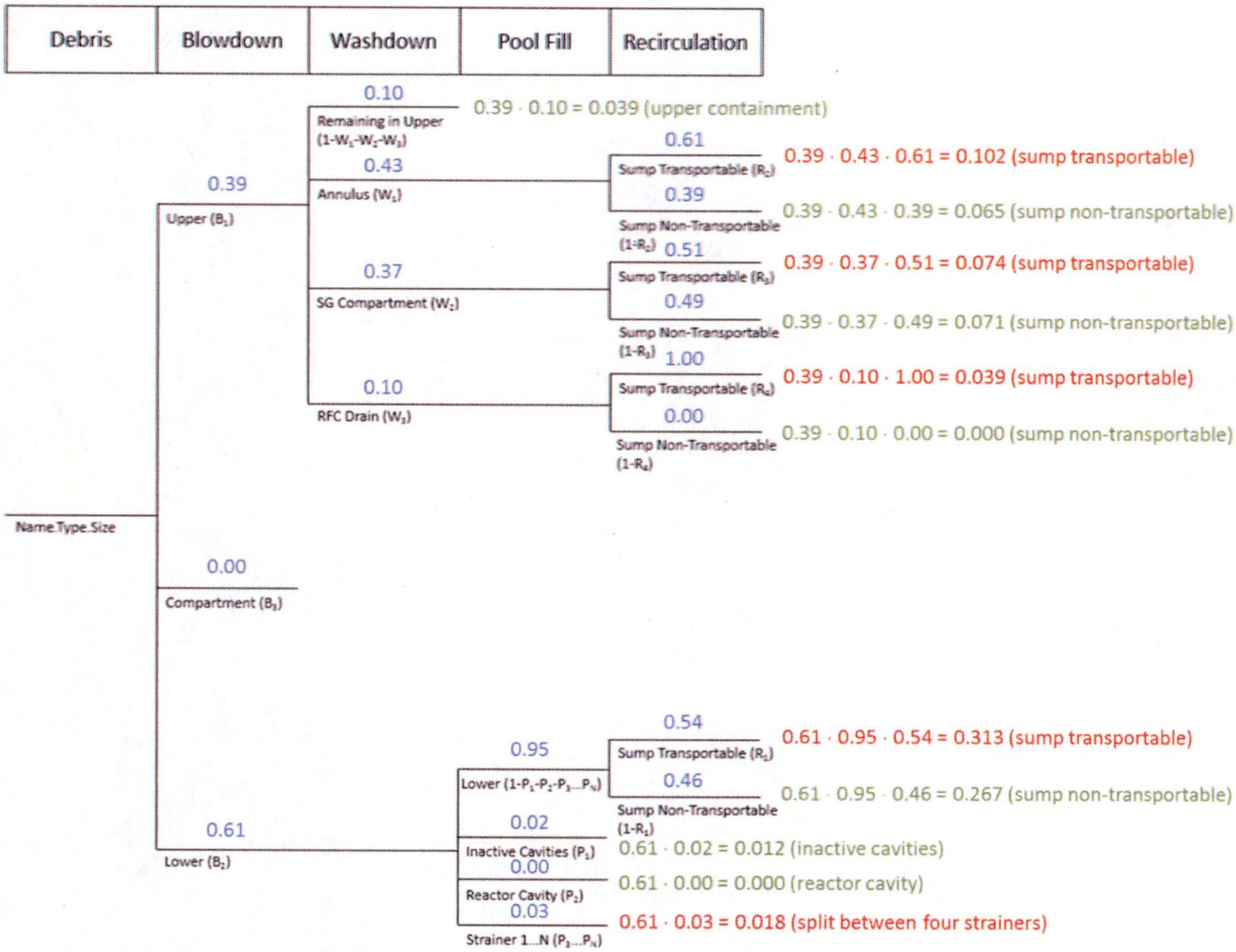

Figure 20-3: NARWHAL debris transport logic tree with example transport fractions

b. The transport fractions for small and large pieces shown in Enclosure 5 Tables 3.e.6-7 through 3.e.6-14 [Ref. 1, pp. E5-51 to E5-54] include erosion fines generated from the small and large pieces. NARWHAL tracks the erosion fines as described below.

c. As discussed in the response to Part a, the debris is distributed prior to the start of recirculation based on the blowdown, washdown, pool fill, and recirculation transport fractions. As described

in Enclosure 3 Section 9.0, a 1% erosion fraction was applied for small and large pieces of fiberglass retained in upper containment and a 10% erosion fraction was applied for debris in the pool (including both the sump transportable and sump non-transportable debris) [Ref. 1, pp. E3-22 to E3-23]. In NARWHAL, the fines generated due to erosion are subtracted from the quantity of small and large pieces and added to the quantity of fines prior to the start of recirculation. This is conservative since early arrival of fines (when the pool temperature is higher) is more detrimental for strainer failures.

NRC RAI 21

For the fiber mass balance, please confirm the adequacy of the penetration model from the information provided in the submittal. Also, please confirm that the filtration and shedding functions included in the mass balance model were compared to the test data using the final set of parameters for NARWHAL calculations.

a. Is the penetration amount based on the total amount of fiber or only the fine fiber arriving at the strainer?

b. Please provide a comparison of the equation predictions with the test data using the parameters for NARWHAL calculations.

SNC Response to RAI 21

a. The penetration evaluation was based only on the amount of fine fiber (including erosion fines generated from small and large pieces) arriving at and collecting on the strainer. Note that the strainer penetration tests were conducted using fine Nukon fiber prepared in accordance with the NEI protocol [Ref. 8], which defines fiber fines as "readily suspendable in water (Classes 1 through 3 of Table 3-2 of NUREG/CR-6808)". As stated in the VEGP fiber penetration test report, the prepared fiber was predominantly Class 2 fiber as defined in NUREG/CR-6224 [Ref. 9]. Note that the same fiber size classification is used in NUREG/CR-6808 [Ref. 10 pp. Table 3-2] and NUREG/CR-6224 [Ref. 9 pp. Table B-3].

The methodology outlined in WCAP-17788 was used in the Vogtle analysis to determine the amount of fiber that would accumulate at the core inlet or within the core. The recirculation phase was divided into small time steps. For each time step, the following computation was performed:

1. The fractions of prompt and shedding penetration are calculated using the model equations based on the quantity of fine fiber collected on the strainer at the beginning of the time step.
2. The amount of fine fiber that arrives at the strainer during the current time step is calculated by multiplying the fine fiber concentration in the pool by the strainer flow rate and time step.

3. The amount of prompt penetration is calculated by multiplying the prompt penetration fraction from Step 1 by the amount of fine fiber arriving at the strainer during the current time step from Step 2.
4. The amount of shedding penetration is calculated by multiplying the shedding penetration fraction from Step 1 by the amount of fiber collected on the strainer at the beginning of the time step.

b. Fiber penetration models were derived for the RHR and CS strainers and their respective operating conditions using the VEGP fiber penetration test data from 9 different tests. As stated in the Response to 3.n.1 in Enclosure 5 of the VEGP submittal, the resulting RHR penetration model predicts higher fiber penetration quantities than all of the actual tests because of the high strainer approach velocity and low chemistry conditions of the RHR strainer, as demonstrated in Figure 3.n.1-3 of Enclosure 5 in the VEGP submittal [Ref. 1, p. E5-139].

   Figure 21-1 shows another comparison between the predicted fiber penetration quantities using the RHR strainer penetration model and the testing results. In the figure, the cumulative fiber penetration quantities are plotted as functions of the quantity of fiber added to the test tank. All debris quantities shown in the figure are normalized by the number of strainer disks. The RHR penetration model was applied to the plant RHR strainer approach velocity and disk number, along with the debris addition sequence of Test 1, Test 3, and Test 8 (e.g., debris introduction timing, duration and quantity). The results are shown in the figure as the thick solid lines. The measured fiber penetration quantities are shown for all 9 tests as the thin solid lines, identified by different markers. As shown in the figure, the predicted fiber penetration quantities for each test bound the measured data points of the corresponding test. Therefore, applying the fiber penetration model is conservative for quantifying fiber penetration for the evaluation of in-vessel downstream effects.

   Note that uncertainty evaluation cases were run to bias the inputs (e.g., sump pool volume, RHR and CS pump flow rates, CS duration, fiber penetration, and LOCA frequency) to maximize strainer failures, as discussed in Section 14.2.3 of Enclosure 3 [Ref. 1, pp. E3-70 to E3-72]. Among the conservative inputs, a 0% fiber penetration fraction was used to maximize the amount of fiber on the strainer. The results (see Table 3-15 in Enclosure 3 [Ref. 1, pp. E3-71]) showed that the conservative combinations of inputs did not challenge the conclusions of the risk quantification.

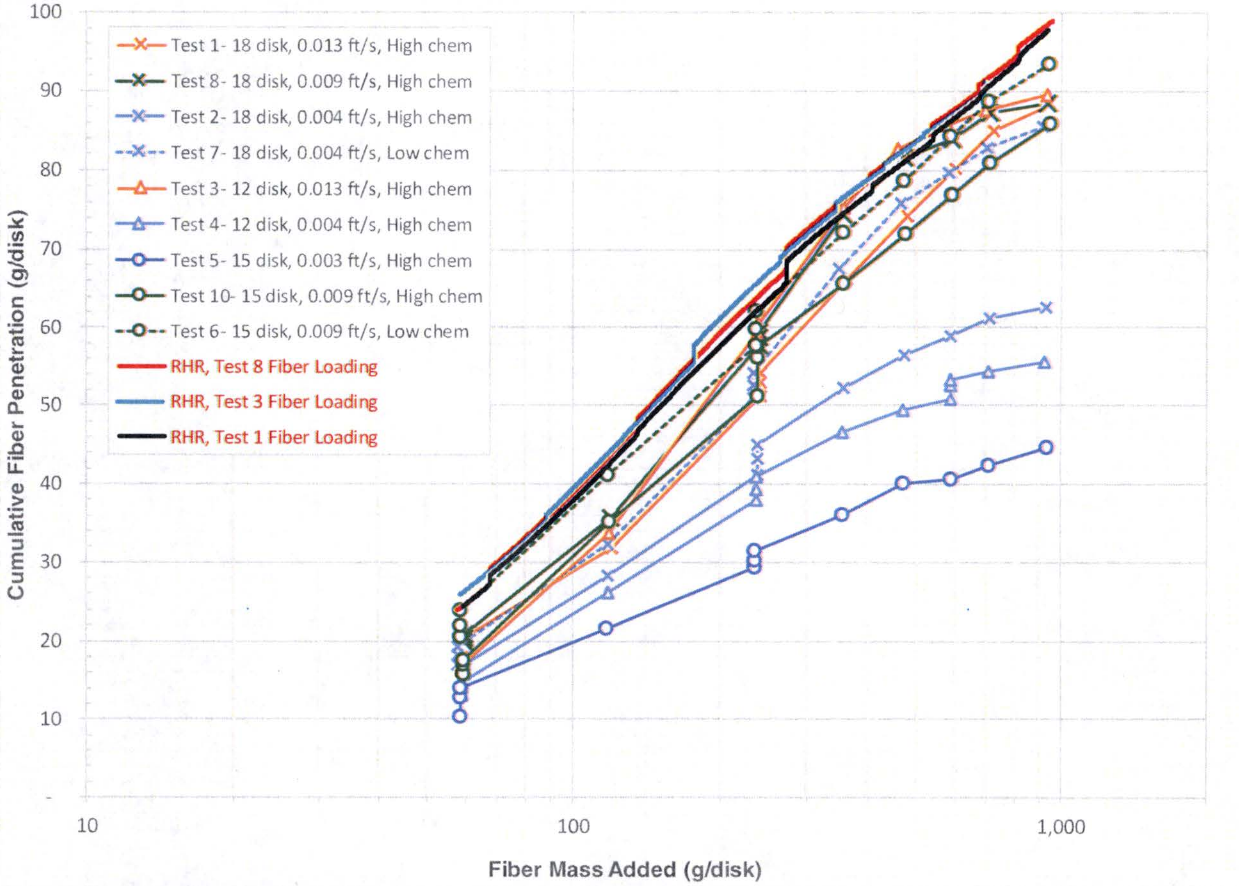

Figure 21-1: Comparison between predicted fiber penetration quantities and test results

NRC RAI 22

The licensee describes the fibrous debris transport in Enclosures 3 and 5. The fine debris was assumed to transport, during blowdown, based on the volumes of lower and upper containment. "Appendix VI: Detailed Blowdown/Washdown Transport Analysis for Pressurized-Water Reactor Volunteer Plant," of the safety evaluation (SE) (ADAMS Accession No. ML050550156) for NEI 04-07, Revision 0, "Pressurized Water Reactor Sump Performance Evaluation Methodology," (ADAMS Accession No. ML050550138) which indicates that a significant amount of small and fine debris would remain in the break compartment due to various capture mechanisms.

a. Please discuss whether the potential for the holdup was considered in the fine and small debris transport analysis and provide the basis for the assumptions used in the fine debris transport analysis.

b. Please discuss the basis for acceptability of assumptions used to simplify the blowdown transport evaluation. For example, holdup in compartments was not

modeled, but debris blown to lower containment was placed directly in the pool to account for uncertainties regarding holdup.

SNC Response to RAI 22

a. As described in Appendix VI of NEI 04-07 Volume 2, a portion of the fine and small piece debris would realistically be trapped by inertial capture as the break flow makes sharp changes in direction [Ref. 4, p. VI-6]. If the captured debris is in a location that is not impinged by containment sprays, the debris would remain attached to those surfaces and would not transport to the strainers [Ref. 4, p. VI-7]. In the Vogtle debris transport analysis, inertial capture was not credited for fine debris. Inertial capture (including miscellaneous structures, grating, and 90° flow turns) was considered for small pieces of fiberglass, but was only used to determine the fraction of debris blown to upper containment; it was not used to credit retention of debris on structures that are not impinged by containment sprays.

b. The following assumptions were made in the debris transport calculation.

    - Fine debris generated by a LOCA was assumed to transport to upper containment in proportion to the ratio of upper containment volume to the total containment volume. This is a reasonable assumption since fine debris generated by a LOCA would easily travel with the blowdown flow. As discussed in the response to Part a above, no credit was taken for inertial capture of fine debris. All fine fiber not blown to upper containment was assumed to be in the containment pool. This is a conservative assumption since a significant fraction of fine debris could be retained on structures above the pool in locations that would not be directly impacted by containment sprays.

    - Small and large pieces of debris were also assumed to transport to upper containment in proportion to the volume ratio of upper containment to total containment; however, consideration was made for variations due to the compartment where each break occurs, such as the amount of grating that debris would encounter and the number of 90° turns in the flow path. As discussed in the response to Part a, these considerations reduced the total fraction of debris blown to upper containment. For breaks in the steam generator compartments, the reactor cavity, and the lower elevation of the annulus, all small and large piece debris that was not blown to upper containment was assumed to be in the pool at the end of the blowdown phase. For breaks in the pressurizer compartment and higher elevations in the annulus, the blowdown fraction of debris was split between upper containment, lower containment (assumed to be in the pool), and debris remaining in the compartment. The pieces of debris remaining in the compartment were treated essentially the same as debris blown to upper containment as shown in Figure 20-2. This methodology is consistent with the approach used for blowdown transport for the volunteer plant in NEI 04-07 Volume 2 [Ref. 4, Appendix VI].

    -

NRC RAI 23

Please explain whether all debris that transports to lower containment is assumed to be in the pool. If it is not, please provide the amounts held up above the pool for each debris type, and the basis for the assumed holdup quantities.

SNC Response to RAI 23

All debris that transports to lower containment (e.g., following blowdown or washdown) is assumed to be in the pool.

NRC RAI 24

In Section 3.h.2 of the submittal, the licensee states:

> It was assumed that 100 percent of unqualified coatings were in the containment pool at the start of recirculation. This is a conservative assumption since no credit is taken for retention of unqualified coatings in upper containment regardless of the failure time or if containment sprays [CSs] are initiated.
>
> It was assumed that the unqualified and degraded qualified coatings in VEGP have a recirculation transport fraction of 100%. This is consistent with the debris transport calculation, and is conservative since settling of this debris is not credited.

In Section 3.h.6 of the submittal, the licensee states:

> In accordance with the guidance provided in NEI 04-07 (Reference 2 [ADAMS Accession No. ML050550138]) and the associated NRC SE (Reference 3 [ADAMS Accession No. ML050550156]), all coating debris was treated as particulate and therefore transported entirely to the sump strainer.

a. Please provide the basis for the transport fractions for the various types of unqualified coating debris listed in Tables 3.e.6-7 through 3.e.6-14 of Enclosure 5. Alternately, provide revised transport values for unqualified coatings in the tables based on the information provided in other sections of the submittal as discussed above.

b. Please explain why the transport fractions vary among the types of unqualified coatings for different break locations and equipment operating states.

SNC Response to RAI 24

a. As noted above, there was an inconsistency in the description of unqualified coatings debris in Enclosure 5 Section 3.e [Ref. 1, pp. E5-51 to E5-54] and Section 3.h [Ref. 1, pp. E5-104 to E5-107]. The debris transport calculation credited the actual location of unqualified coatings (i.e., the split between upper containment and lower containment). As shown in Table 3.e.6-2, the washdown transport for debris in upper containment is much lower when containment sprays are not initiated [Ref. 1, p. E5-47]. Taking credit for the actual distribution of the unqualified coatings results in less than 100% transport for certain scenarios, as reflected in Tables 3.e.6-8 through 3.e.6-12 [Ref. 1, pp. E5-51 to E5-53].

However, taking credit for a portion of the unqualified coatings being in upper containment is not consistent with the statement in Enclosure 5 Section 3.h.2 that 100% of the unqualified coatings were assumed to be in the containment pool at the start of recirculation [Ref. 1, p. E5-105]. The NARWHAL evaluation for Vogtle used the assumption that 100% of the unqualified coatings were in the containment pool at the start of recirculation. Therefore, other than the overall debris transport tables discussed above [Ref. 1, pp. E5-51 to E5-53], everything in the submittal (e.g., the transported debris quantities shown in Tables 3.e.6-15 and 3.e.6-16 [Ref. 1, E5-56 to E5-57] and the sensitivity analysis and uncertainty quantification results shown in Enclosure 3 [Ref. 1, pp. E3-61 to E3-75]) was based on the assumption that 100% of the unqualified coatings were in the containment pool at the start of recirculation.

Due to a separate issue related to unqualified coatings, which is discussed in RAI 35 and the associated response, the Vogtle NARWHAL model was recently revised to take credit for the distribution of unqualified coatings in upper and lower containment. The distribution that is now credited is shown in Table 24-1.

Table 24-1: Unqualified coatings debris quantities

Unqualified Coating Type	Upper Containment Quantity (ft^3)	Lower Containment Quantity (ft^3)
Epoxy	17.671	12.711
IOZ	0.117	0.265
Alkyd	0.000	0.516

Note that unqualified coatings initially located in lower containment are assumed to fail directly into the sump at the beginning of the event. Unqualified coatings initially located in upper containment are dependent on washdown transport to reach the sump. As described in Enclosure 3 Section 9.0, when containment sprays are initiated, the washdown fraction for fine debris is 100% and when containment sprays are not initiated, the condensation washdown fraction for fine debris is 10% [Ref. 1, p. E3-22]. Since the unqualified coatings are assumed to fail as fines [Ref. 1, p. E5-29], recirculation transport to the active strainers is 100%.

b. As discussed in the response to Part a, crediting the initial distribution of unqualified coatings in upper containment will result in different overall transport fractions depending on whether the containment sprays are initiated.

NRC RAI 25

Please provide the bases for the overall latent debris transport fractions for the non-spray cases in Tables 3.e.6-8 through 3.e.6-12.

SNC Response to RAI 25

Similar to the inconsistency in the unqualified coatings debris transport described in the response to RAI 24, there was also a discrepancy in the overall debris transport fractions for latent debris in Tables 3.e.6-8 through 3.e.6-12 [Ref. 1, pp. E5-51 to E5-53]. The debris transport calculation took credit for 75% of the latent debris being in upper containment, which resulted in some latent debris being retained in upper containment for cases where the containment sprays are not initiated.

However, for the NARWHAL model it was conservatively assumed that 100% of the fine debris is in the containment pool at the start of the event. Given that 2% transports to the inactive elevator cavity and 3% transports to the four strainers during the pool fill phase [Ref. 1, p. E5-47], 95% of the latent debris would be in the active pool at the start of the recirculation phase. The recirculation transport fraction for fine debris is 100% [Ref. 1, p. E5-46], resulting in a total overall transport of 98% to the strainers (3% pool fill transport plus 95% recirculation transport). The treatment of latent debris was not changed in the recent modifications to the NARWHAL model discussed in the response to RAI 24.

NRC RAI 26

Section 3.e.1 of Enclosure 5 states that the location of each type and size of debris at the beginning of recirculation was determined based on the location of the break. Larger debris may remain closer to the break location. Section 3.e.6 describes recirculation transport cases that were applied to various break locations.

a. Please describe how debris locations at the start of recirculation were determined, including the effects of blowdown, pool fill, and washdown. If the some of the effects are not accounted for in the model, please describe how the evaluation ensures that the model is conservative. Alternatively, please confirm that risk is not underestimated.

b. Please describe which recirculation transport cases from Tables 3.e.6-4 through 3.e.6-6 were applied to corresponding break location cases.

c. Please clarify whether the CFD results used in the transport analysis were steady state values input at the start of the recirculation transport or if the values were changing based on stagnant conditions at the start of recirculation.

d. Please describe the difference between recirculation transport cases 1 and 5.

SNC Response to RAI 26

a. As described in the response to RAI 20, the debris that is determined to transport during recirculation (based on the CFD results) is considered "sump transportable" in NARWHAL, and is essentially treated as being uniformly distributed in the sump pool in the NARWHAL model. Therefore, the following description of the debris distributions is only applicable for calculating the recirculation transport fractions, which are used as inputs to NARWHAL.

   To determine the recirculation transport fractions for various types and sizes of debris, the initial debris distributions were overlaid on top of the CFD results to calculate the fraction of the initial distribution area where debris would transport to the strainers. The distribution of debris at the start of recirculation varies based on debris size and whether the debris was initially blown to the containment floor or washed down by containment sprays.

   Containment pool debris distributions were defined for fine debris (including latent debris and unqualified coatings, as well as Nukon, fire barrier, and qualified coatings fines generated inside the ZOI). However, because very low turbulence is required to transport fine debris, the recirculation transport fraction for all fine debris is 100% regardless of the initial distribution in the containment pool.

   For the breaks inside the secondary shield wall, small and large pieces of insulation debris blown to the containment pool were assumed to be uniformly distributed inside the secondary shield wall. This is reasonable since the blowdown and the majority of the pool fill phases are multidirectional flows that would tend to disburse debris around the area inside the secondary shield wall (including areas with lower transport potential). The small piece debris blown to upper containment was assumed to be distributed in the vicinity of the locations where it is washed down. For breaks in the annulus that are near or far from the sump strainers, small and large pieces of debris were assumed to be distributed near the break location.

   Figure 26-1 through Figure 26-4 graphically depict the initial debris distribution areas for the various types/sizes of debris. Figure 26-1 shows the distribution area of small piece debris washed down from upper containment to the steam generator compartments inside the secondary shield wall (SSW), through the refueling canal (RFC) drain, and to the annulus. Figure 26-2 shows the distribution area for small and large piece debris for breaks in the steam generator compartments. Figure 26-3 and Figure 26-4 show the distribution area for small and large piece debris for breaks in the annulus near and far from the sump strainers, respectively.

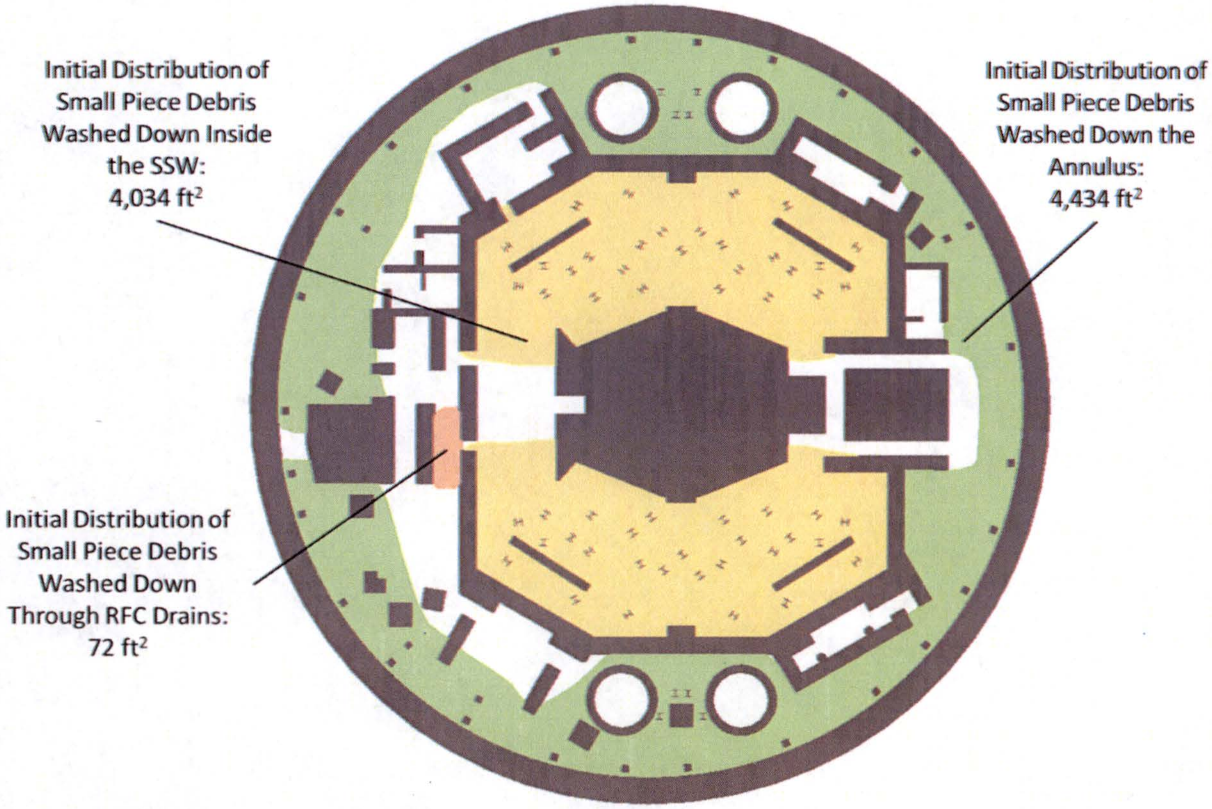

Figure 26-1: Distribution of small piece debris washed down from upper containment

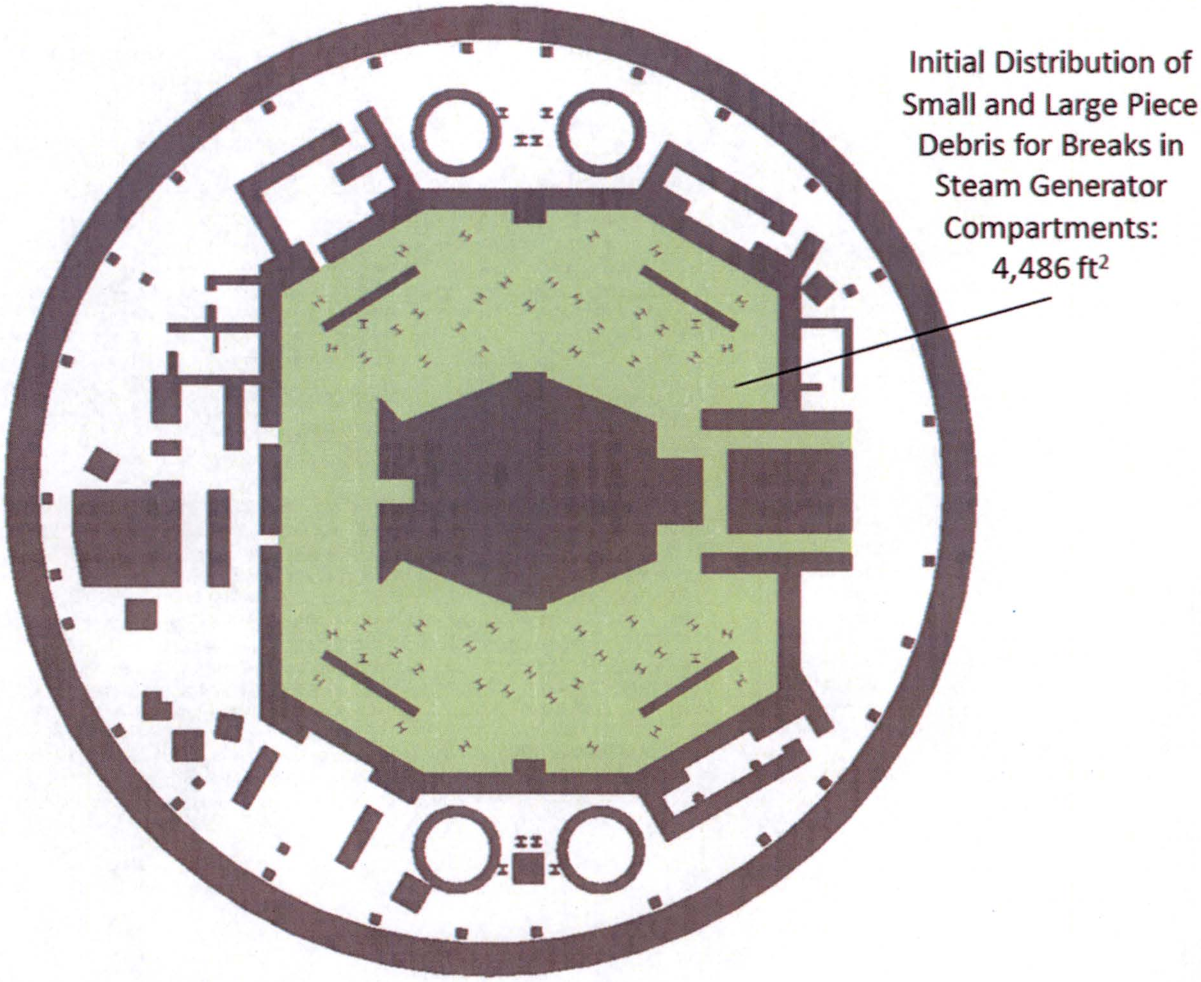

Figure 26-2: Distribution of small and large piece debris in lower containment for breaks in the steam generator compartments

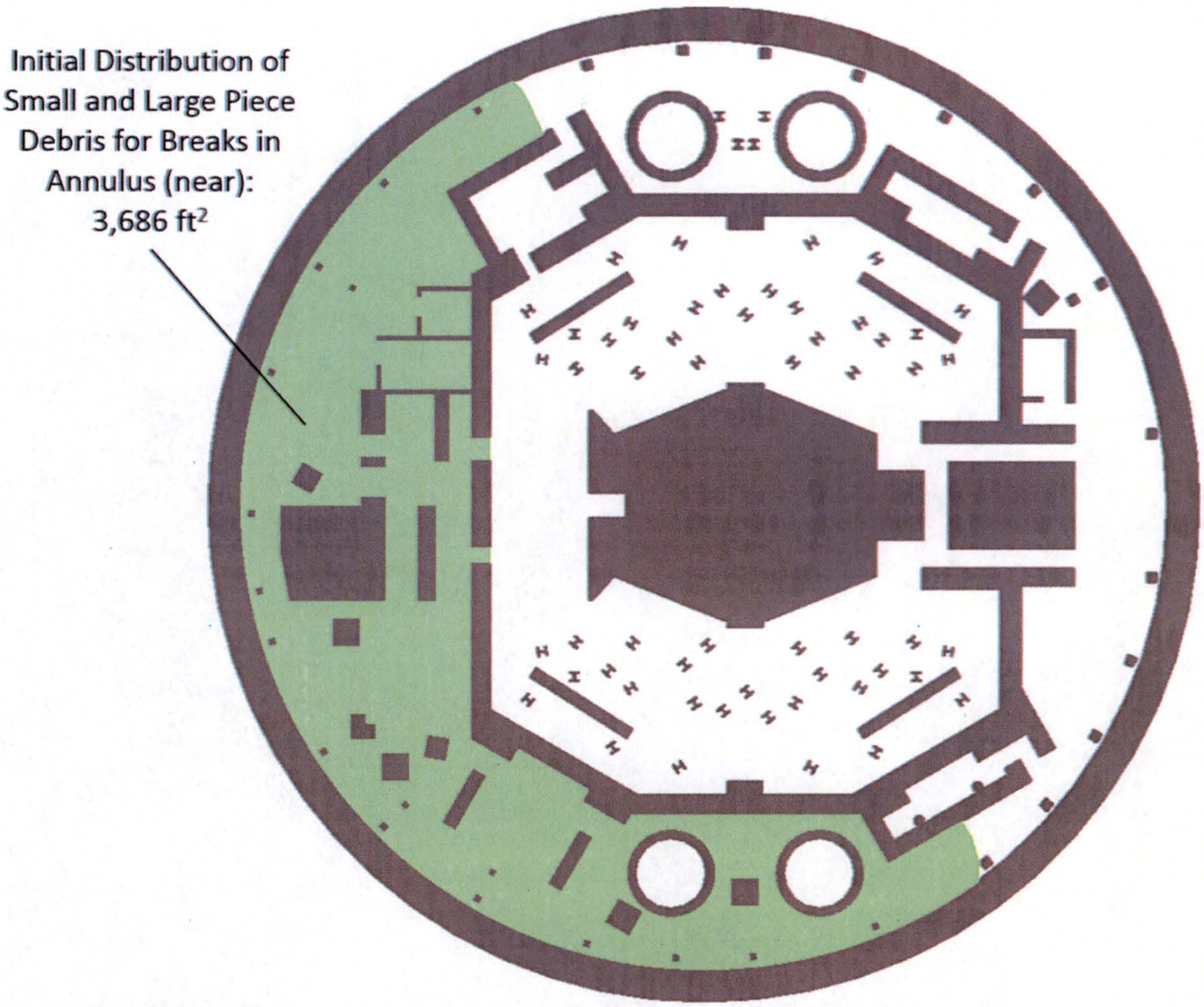

Figure 26-3: Distribution of small and large piece debris in lower containment for breaks in the annulus (near sump strainers)

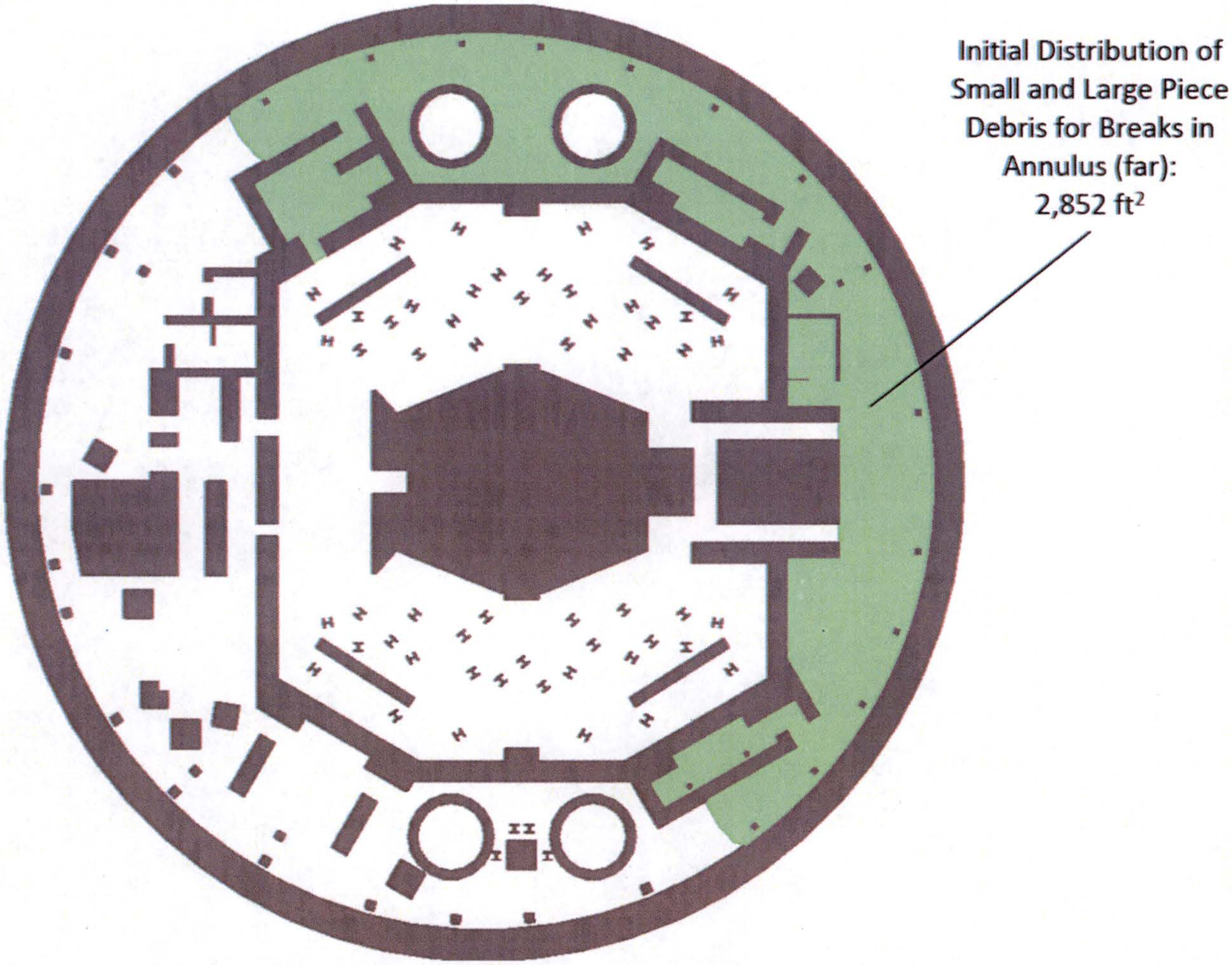

Figure 26-3: Distribution of small and large piece debris in lower containment for breaks in the annulus (far from sump strainers)

b. The recirculation debris transport fractions from the various CFD cases shown in Enclosure 5 Tables 3.e.6-4 through 3.e.6-6 [Ref. 1, pp. E5-48 to E5-50] were applied in the various break scenarios and equipment configurations as shown in Table 26-1. See the response to Part d for a description of the inputs used for each case.

Table 26-1: CFD Transport Fraction Cases

Break Location	Containment Spray Activation	Active Trains	CFD Case
Steam Generator Compartments 1 & 4	Off	2	Case 1
Steam Generator Compartments 1 & 4	On	1 or 2	Case 7
Steam Generator Compartments 1 & 4	Off	1	Case 4
Steam Generator Compartments 2 & 3	Off	2	Case 1
Steam Generator Compartments 2 & 3	On	1 or 2	Case 6
Steam Generator Compartments 2 & 3	Off	1	Case 4
Reactor Cavity	Off	2	Case 1
Reactor Cavity	On	1 or 2	Case 7
Reactor Cavity	Off	1	Case 4
Pressurizer Compartment	Off	2	Case 1
Pressurizer Compartment	On	1 or 2	Case 7
Pressurizer Compartment	Off	1	Case 4
Annulus	Off	2	Case 2
Annulus	On	1 or 2	Case 7
Annulus	Off	1	Case 2

c. Steady state conditions were used to calculate the recirculation debris transport fractions.

d. The difference between Cases 1 and 5 is the water level used for the CFD simulations. For both cases, the recirculation transport fraction for fine debris is 100% and the recirculation transport fraction for small and large piece debris is 0% as shown in Enclosure 5 Tables 3.e.6-4 through 3.e.6-6 [Ref. 1, pp. E5-48 to E5-50]. The break location, equipment configuration, flow rates, and water levels used for each simulation are shown in Table 26-2. Note that Cases 3 and 5 were not used for any breaks analyzed in NARWHAL since the debris transport fractions from these cases were bounded by Cases 2 and 1, respectively [Ref. 1, pp. E5-48 to E5-50].

Table 26-2 – Summary of CFD Simulation Inputs

Case	Break Location	Break Size	Trains Operating	CS Sprays On/Off	Flow Rates	Water Level
1	Loop 4 Crossover Leg	LBLOCA	2 Trains	Off	3,734 gpm/RHR	6.597 ft
2	Pressurizer Surge Line in Annulus	LBLOCA	2 Trains	Off	3,734 gpm/RHR	6.597 ft
3	Accumulator Injection Line in Annulus	LBLOCA	2 Trains	Off	3,734 gpm/RHR	6.597 ft
4	Loop 4 Crossover Leg	LBLOCA	Train B	Off	4,500 gpm	6.597 ft
5	Loop 4 Crossover Leg	LBLOCA	2 Trains	Off	3,734 gpm/RHR	7.534 ft
6	Loop 2 Crossover Leg	LBLOCA	2 Trains	On	4,500 gpm/RHR 3,200 gpm/CS	5.25 ft
7	Loop 4 Crossover Leg	LBLOCA	2 Trains	On	4,500 gpm/RHR 3,200 gpm/CS	5.25 ft

NRC RAI 27

In Enclosure 5, the licensee describes debris capture on and debris penetration through the sumps. Please confirm that the Vogtle testing used to develop the penetration model was biased to increase penetration amounts. The staff has reviewed the submittal including the sensitivity studies and uncertainty analyses related to in-vessel downstream effects. It is not apparent that the licensee has determined the final methodology it will use to evaluate the effects of debris that may enter the reactor vessel.

Please describe how SNC will ensure that there is no significant increase in uncertainty, that sensitivity studies remain applicable and bounding for the methods and assumptions used to evaluate in-vessel effects, or that no significant increase in risk is apparent.

SNC Response to RAI 27

SNC intends to use WCAP-17788 for the final evaluation of in-vessel effects [Ref. 11]. Once WCAP-17788 is accepted by the NRC, SNC will determine whether any changes to the methodology and/or acceptance criteria in the approved version impact the in-vessel downstream effects evaluation. If so, the evaluation will be revised to incorporate the changes and the risk quantification, uncertainty quantification, and sensitivity studies will be updated accordingly. The updated results will be summarized in the License Amendment Request (LAR) that will be submitted to the NRC for review.

NRC RAI 28

Please confirm that the clean strainer head loss is 4.40 inches of water as described in on Page E5-75 in Section 3.f.9 of Enclosure 5. On page E5-81 in Section 3.f.10, the bounding clean strainer head loss is listed as 4.40 ft.

SNC Response to RAI 28

The value shown in Section 3.f.10 (4.40 ft) was a typo. The clean strainer head loss is 4.40 inches. This value was rounded up to 4.5 inches (0.375 ft) in the NARWHAL model, as stated in Section 10.1 of Enclosure 3 in the VEGP GL Submittal [Ref. 1, p. E3-24].

NRC RAI 29

In Sections 3.g.1, 3.g.2, 3.g.8, and 3.o.2 of Enclosure 5, the licensee states that sump levels were calculated using the NARWHAL software and hand calculations. In addition, hand calculations were used for the vortex analysis and chemical effects evaluation.

a. Please describe how did the NARWHAL level calculations compare to the hand calculations.

b. Does Vogtle have a containment analysis code (e.g., GOTHIC) that can be used to calculate sump level? If so, please provide a comparison of the containment analysis results to those used in the risk analyses. Alternately, provide a comparison to design basis level values.

SNC Response to RAI 29

a. The water level for a large break LOCA (LBLOCA), outside the reactor cavity, and that activates containment sprays was calculated by hand using conservative inputs to minimize the water level. The water levels at various times for this scenario are shown in Table 29-1 [Ref. 1, p. E5-91].

Table 29-1: Minimum Water Level for an LBLOCA Outside the Reactor Cavity with Containment Spray Activated

Time	Hand Calculation Minimum Pool Level (ft)
Sump Suction Valves Open	4.536
Completion of Switchover	6.241
5.5 Hours	6.058
60 Hours	5.311

The NARWHAL model uses many inputs that are consistent with the hand calculation. However, the hand calculation includes some additional conservatisms that are not included in the

NARWHAL model. The following items are the most significant differences between the NARWHAL calculated pool level and the hand calculations:

- The minimum level hand calculation assumed a break at the highest elevation of the RCS (above the top of the pressurizer), which results in a significantly larger RCS hold-up volume compared to a break at a lower elevation. In NARWHAL, RCS hold-up is based on the break-specific elevation (i.e., the maximum RCS hold-up volume is applied for breaks at the highest elevations such as the pressurizer spray line piping, and smaller hold-up volumes are applied for breaks at lower elevations such as the pressurizer surge line or primary loop piping).
- The hand calculation assumed a pool temperature of 100°F to maximize the pool water density and minimize the pool water level. NARWHAL calculates the pool density as a function of the time-dependent pool temperature, which is significantly higher than 100°F early in the event [Ref. 1, p. E5-86].

The NARWHAL calculated pool level is shown in Table 29-2 for a 19-inch hot leg break at Weld 11201-003-5-RB. The hand-calculated water level was adjusted to use an RCS hold-up volume consistent with the hot leg break elevation, as well as pool temperatures that are consistent with the design basis pool temperatures used in NARWHAL. As shown in the table, the results are very similar, and only vary slightly due to simplifications made in the hand calculation for time-dependent input parameters.

Table 29-2: Water Level Comparison for an LBLOCA with Containment Spray Activated

Time	NARWHAL Calculation Pool Level (ft)	Hand Calculation Minimum Pool Level (ft)
Sump Suction Valves Open	5.365	5.271
Completion of Switchover	6.976	6.989
5.5 Hours	6.411	6.579
60 Hours	5.763	5.726

b. SNC did not use a containment analysis code to calculate post-LOCA water levels. Please see the response to Part a for a comparison with the design basis minimum water level values.

NRC RAI 30

One assumption of the analysis is that the CSs actuate only for hot-leg breaks greater than 15 inches. The staff reviewed the model uncertainty study summarized in Tables 3-16 and 3-17 and observed that the effects of CS operation following small-break loss-of-coolant accident (i.e., less than 2 inches) does not appear to have been evaluated.

> Please confirm that the CSs are not started by operator action in response to loss-of-coolant accident scenarios not covered by the uncertainty analysis (breaks less than 2 inches), including for the control of fission products. Alternatively, please demonstrate that operation of sprays under these scenarios does not significantly affect risk.

SNC Response to RAI 30

The emergency operating procedures do not direct the operators to manually start containment spray. Although the operators could start containment sprays following a small break LOCA (SBLOCA), it is not likely that this would occur since the release of fission products in containment would be minimal unless a failure resulting in core damage has already occurred.

As shown in Table 3-17 of Enclosure 3, there was no difference between the sensitivity case where containment sprays were assumed to initiate for all breaks larger than 6 inches and the case where containment sprays were assumed to initiate for all breaks larger than 2 inches [Ref. 1, p. E3-74]. This is due to the fact that no failures occurred for any medium break LOCAs (MBLOCAs) (defined as 2-inch to 6-inch breaks) either with or without containment sprays operating. As shown in Enclosure 5 Section 3.a.3, the quantity of ZOI-generated debris is very small for MBLOCAs, and essentially negligible for SBLOCAs [Ref. 1, pp. E5-16 and E5-21]. Therefore, operation of the containment sprays for SBLOCAs would not significantly affect risk.

NRC RAI 31

> Enclosure 5, Section 3.i.3, does not state whether aluminum and calcium sources within containment are controlled. Are the source terms for potential chemical effects in the sump pool evaluated within the design change process?

SNC Response to RAI 31

As shown in the VEGP containment sump pool chemical effects calculation, the aluminum release into the sump pool is dominated by aluminum metal inside the containment. An SNC fleet engineering guideline directs the engineers to evaluate any impact on the amount of reactive metals (i.e., zinc and aluminum) due to plant modifications. For VEGP, the inventory of aluminum metal inside the containment is tracked in a calculation that addresses both chemical effects for GSI-191 and post-accident hydrogen generation.

The main source for calcium release is the insulation materials, for example, Calcium Silicate, Mineral Wool and E-Glass. As stated in the Response to 3.i.3 in Enclosure 5, the VEGP design change procedure already incorporates requirements for reviewing the impact of proposed changes on insulation materials inside the containment [Ref. 1, p. E5-109].

NRC RAI 32

Enclosure 5, Section 3.I.4 states that the Vogtle limiting break with respect to upstream flow blockage occurs under the operating deck and inside the secondary shield wall. For breaks within these bounds, the analysis shows that debris large enough to potentially block the refueling cavity drains cannot credibly reach the refueling cavity. Are there breaks in other locations that could allow debris to transport to and block the refueling cavity drains? If yes, please describe how the potential for sump inventory holdup in the refueling cavity is addressed for these cases.

SNC Response to RAI 32

As discussed in Enclosure 2 Section 3.I.4, the refueling cavity has two 12-inch drains. Given the size of the drains, it is unlikely that they would be clogged unless a significant amount of large piece debris transported to the refueling canal. As shown in Figure 32-1, there are numerous levels of grating throughout the steam generator compartments, annulus, and pressurizer compartment that would prevent large pieces of debris from reaching the refueling cavity. A break in a pipe at the top of the pressurizer compartment could allow debris to transport to the refueling cavity without passing through grating. However, since the largest source of insulation in this area is on the pressurizer, which would be below the break, the debris would tend to be blown downward with minimal transport of any large pieces out of the pressurizer compartment.

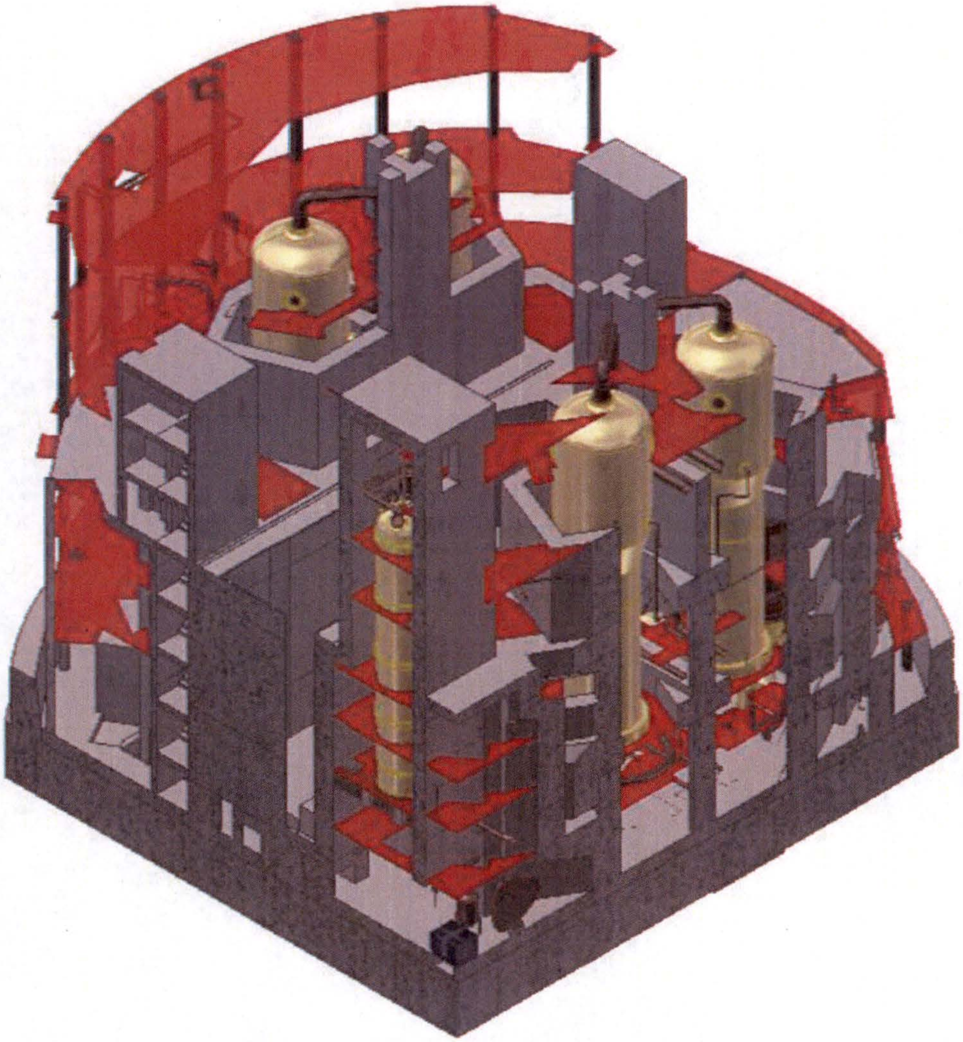

Figure 32-1: Section view of containment CAD model

NRC RAI 33

In Section 3.n.1 of Enclosure 5, the licensee describes fiber penetration testing performed for Vogtle's strainers. The section states that the first two batches consisted of fiber equal to 1/16 inch bed thicknesses, the third through seventh batches consisted of fiber equal to 1/8 inch bed thicknesses, and the final batch consisted of fiber equal to a 1/4 inch bed thickness. Considering the skewed distribution of fiber on the strainer observed during head loss testing, please justify that the batches added after the initial two batches did not result in bypass results less than the bypass that may have occurred with smaller batches.

SNC Response to RAI 33

Although the batching size increased after the first two batches, this had little effect on the test results because the fiber concentration was maintained sufficiently low. Small-scale fiber penetration testing

performed by VEGP demonstrated that fiber concentrations ranging between 0.00052 and 0.0177 ft^3 of fiber/ft^3 of water in the test tank had insignificant effects on fiber penetration. During the large-scale fiber penetration testing, the debris concentration was controlled by adjusting the addition time of each batch. The peak fiber concentrations were controlled below ~0.005 ft^3 of fiber/ft^3 of water for all batches. This concentration is enveloped by the range of concentrations studied in the small-scale testing. Therefore, it is reasonable to conclude that the batching size had little effect on the measured fiber penetration.

NRC RAI 34

> In Section 3.f.3 of Enclosure 5, the licensee discusses vortexing of plant strainers (i.e., air ingestion). In Section 4 of Enclosure 5, the licensee provides responses to previous RAIs. Is the issue of the potential for air ingestion as discussed in RAI 22 on page E5-183 addressed by limiting the volume of debris to that included in the testing and assigning all cases with larger debris loads to failure, combined with decreasing the strainer height?

SNC Response to RAI 34

The understanding of the Response to RAI 22 as stated above is correct. The response to vortexing in Section 3.f.3 of Enclosure 5 was based on the observations made during the head loss testing [Ref. 1, pp. E5-62 to E5-64]. For the tested debris loads, it was shown that vortexing will not impact the operation of the strainers. All breaks that have debris loads exceeding those tested were already assumed to fail, as stated in Section 3.f.5 of Enclosure 5 [Ref. 1, p. E5-72].

NRC RAI 35

> In Section 3.f.4 of Enclosure 5, the licensee states that green silicon carbide powder was used as a surrogate for coatings during head loss testing. The licensee further states that the mass of the surrogate was adjusted based on the difference in density between the surrogate and plant coatings so that the volumes of the coatings in the plant were modeled in the test. The NRC staff also reviewed the Calculation No. ALION-CAL-SNC-7410-005, Revision 1 "Head Loss Testing of a Prototypical Vogtle 1 and 2 Strainer Assembly," August 13, 2015 (ADAMS Accession No. ML15293A187), and noted that the plant coatings were described as having a density of about 200 pounds per cubic foot (Table 2.2.2-2 in the calculation). According to Section 3.h of Enclosure 5, there is a significant amount of epoxy coatings in the plant. In general, epoxy has a density of about 100 pounds per cubic foot (see Table 3.c.1-1 in Enclosure 5).
>
> Please describe how the mass of coatings surrogates used in head loss testing was adjusted to account for the difference in density between the plant coatings and the surrogate material such that the volume of particulate debris was conserved in the testing. If the difference in density was not accounted for in the testing, please describe how the analysis is adjusted to accommodate additional plant debris.

SNC Response to RAI 35

When comparing the quantity of generated and transported particulate debris to the quantity of tested particulate debris, the comparison was incorrectly made on a mass basis rather than a volume basis. The error was corrected by modifying the NARWHAL model to compare the cumulative volume of qualified coatings, unqualified coatings, and dirt/dust particulate to the volume of particulate surrogate included in the head loss tests. Because the test surrogate (silicon carbide) has a higher density than most of the plant particulate debris, the total volume of unqualified coatings exceeds the tested volume for many scenarios that were previously shown to pass. To address this issue, a simple refinement was incorporated to take credit for the distribution of unqualified coatings in upper and lower containment. As discussed in the response to RAI 24, this distribution had already been determined as part of an earlier effort, but was not previously credited in the NARWHAL model.

For breaks that do not initiate containment sprays, there would only be a small fraction of unqualified coatings washed down from upper containment due to condensation flow [Ref. 1, E3-22]. For breaks that do initiate containment sprays, all of the unqualified coatings would be washed down to the containment pool and would transport to the active strainers. However, the operation of at least one CS pump would result in the particulate debris being split between multiple strainers (i.e., at least one RHR strainer and one CS strainer).

As discussed in the response to RAI 11 Part a [Ref. 2, pp. E-2 to E-3], the net effect of correcting the particulate volume issue and incorporating the initial distribution of unqualified coatings in the NARWHAL model resulted in the same conditional failure probabilities that were calculated using the original model.

NRC RAI 36

> Enclosure 5, Section 3.g.16 states that the CS pumps are expected to have greater net positive suction head (NPSH) margins than the RHR pumps due to lower flow rates and lower debris loads. Please describe the assumptions used in the NPSH margin calculations that determined that the CS margins are bounded by the RHR margins or explain how the CS pump operation is evaluated in the analysis.

SNC Response to RAI 36

In the NARWHAL analysis, pump NPSH margins were evaluated for both the RHR and containment spray (CS) pumps. The evaluation for the CS strainers used CS-specific inputs for the elevation at the pump inlet, suction piping head loss, and NPSH required, along with strainer head losses determined from the same rule-based debris head loss model (see Section 3.f.10 of Enclosure 5 [Ref. 1, pp. E5-77 to E5-83]). The NARWHAL outputs showed consistently higher (and therefore less limiting) NPSH margins for the CS pumps, compared with the RHR pumps. Note that the CS pumps and strainers were evaluated against all of the failure criteria described in Section 3.f.7 of Enclosure 5 [Ref. 1, pp. E5-73 to E5-74]. However, as described in Section 3.0 of Enclosure 3, CS failures were not included in the GSI-

191 conditional failure probabilities because the sprays are not required for containment cooling [Ref. 1, pp. E3-5 to E3-6].

References

1. **ML17116A098.** Vogtle Electric Generating Plant - Units 1 & 2 Supplemental Response to NRC Generic Letter 2004-02. April 21, 2017.
2. **NL-17-2045.** Vogtle Electric Generating Plant-Units 1&2, Systematic Risk-Informed Assessment of Debris Technical Report SNC Responses to NRC Request for Additional Information (RAIs #11-14). January 9, 2018.
3. **NEI 04-07 Volume 1.** *Pressurized Water Reactor Sump Performance Evaluation Methodology.* Revision 0 : December 2004.
4. **NEI 04-07 Volume 2.** *Safety Evaluation by the Office of Nucelar Reactor Regulation Related to NRC Generic Letter 2004-02.* Revision 0 : December 2004.
5. **NUREG-1829 Volume 1.** *Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process.* April 2008 : s.n.
6. **NUREG/CR-6928.** Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants. February 2007.
7. **NUREG/CR-6928.** Component Reliability Data Sheets 2015 Update. February 2017.
8. **Nuclear Energy Institute.** *ZOI Fibrous Debris Penetration: Processing, Storage and Handling.* Revision 1 : January 2012.
9. **NUREG/CR-6224.** *Parametric Study of the Potential for BWR ECCS Strainer Blockage due to LOCA Generated Debris.* October 1995 : s.n.
10. **NUREG/CR-6808.** Knowledge Base for the Effect of Debris on Pressurized Water Reactor Emergency Core Cooling Sump Performance. February 2003.
11. **WCAP-17788-NP Volume 1.** *Comprehensive Analysis and Test Program for GSI-191 Closure (PA-SEE-1090).* July 2015 : Revision 0.