NuScale Closure Plan for Structural and Seismic

FSAR Tier 2, Sections 3.7 and 3.8 RAIs

The attached closure plan for the NuScale structural and seismic RAIs includes:

- eRAI number and RAI Question #
- RAI Question
- Plan – includes approach and actions to be performed for closing and completing each response, schedule for submitting the final responses and identification of FSAR markups
- Schedule – estimated date of RAI response and FSAR markup submittal

NuScale Closure Plan for FSAR Sections 3.7 and 3.8 RAIs					
	eRAI	Question#	RAI Question	Plan	Schedule
1	8967	03.08.04-4	FSAR Section 3B.2.3.3 states “Pilasters are added to the exterior walls of the RXB structure to increase the capacity at the corners and stiffness of the walls between the corners. The phrase “to increase the capacity at the corners” is unclear to the staff as to what kind of capacity. Clarify the failure mode and structural demand for which the corner pilasters provide additional capacity. Also, clarify whether the phrase, “to increase …..stiffness of the walls between the corners,” refers to additional wall strength provided by the pilasters. Describe the failure mode and structural demand for which the pilasters provide additional wall strength, as applicable.	1) Clarify the failure mode and structural demand for which the corner pilasters provide additional capacity. Provide in response and update FSAR Appendix 3B.2.3.3 to clarify statements in question. RXB pilasters strengthen the exterior walls by resisting axial tension and compression, lateral shear loading in both north-south and east-west direction, flexural bending about the north-south and east- west axes of the pilasters. Failure modes of the concrete walls and pilasters due to the aforementioned loads are described in ACI 349- 06. 2) Clarify any FSAR phrase that discusses additional wall strength provided by the pilasters. First paragraph of 3B.2.3.3 will be restated as follows: Pilasters are used around the perimeter of the RXB exterior walls. They are also used at two locations inside the pool walls from Elevation 50' to Elevation 100' at grid line 3. 3) Describe the failure mode and structural demand for which the pilasters provide additional wall strength. Details regarding the pilasters will be provided in response to Question 03.08.04-6	3/2/2018
2	8967	03.08.04-5	FSAR Section 3B.2.3.3 states “In the finite element model, the pilasters are modeled with frame elements with stiffness properties that represent the combined action of the walls (modeled with shell elements) and the pilasters.” Describe the process to establish the frame stiffness properties that represent the combined action of the walls and the pilasters. Describe what portion of the wall contributes to the frame element stiffness properties.	1) RAI response will clarify the process to establish the frame stiffness properties that represent the combined action of the walls and the pilasters. SAP2000 and SASSI 2010 model walls as shell elements and the pilasters as frame elements. The stiffness of the pilaster is increased in both models to account for the increased bending stiffness of the pilaster stem within the area of the wall. The pilaster also mobilizes parts of the wall on either side of the pilaster. Calculation will be provided in response to show bending stiffness. Figures, from the reactor building structural analysis, will also be provided in the response to show wall dimensions of typical wall and pilaster areas 2) Clarify what portion of the wall contributes to the frame element stiffness properties. In SAP2000 and SASSI2010, the walls are modeled with shell elements and	3/2/2018

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				the pilasters are modeled with frame elements (at the common central line or the neutral axis of the wall) interconnected with the wall. 3) Update FSAR 3B.2.3.3 to clarify that the pilasters are modeled with frame elements with transverse flexural stiffness properties that represent the combined action of the walls and the pilasters.	
3	8967	03.08.04-6	FSAR Section 3B.2.3.3 states "Bending about the weak axis does not need to be evaluated because the pilaster is an integral part of the wall and bending in that direction is not local behavior. It is part of the in- plane behavior of the wall and the shell elements in this area have adequate reinforcing." Further this section states "If the 5 feet by 10 feet pilaster can resist the resulting loads on its own, the pilaster is considered qualified." Provide the magnitude of loadings (bending moments in both strong and week axes, and axial and horizontal forces) at the top of each of the 5' by 10' pilasters and the 4 corner pilasters.	1) Provide the magnitude of loadings (bending moments in both strong and weak axes, and axial and horizontal forces) at the top of each pilaster. These loadings will be provided in a table for the corner and internal pilasters at the N-W, N-E, S-E, and S-W corners and the north, south, east and west walls. These loads envelope the cracked and uncracked concrete conditions, as well as the single and triple building models. The loads come from a load combination that is approximately equivalent to ACI 349-06 load combination 9-6. The load combination forming the basis for these top of pilaster loads is: U = D + F + 0.8L + S + Ccr + H + Ess No FSAR updates will be provided with this response.	3/2/2018
4	8967	03.08.04-7	FSAR Section 3B.2.3.3 states "The shear in the weak axis direction, parallel to the wall, does not need to be evaluated because the in-plane capacity of the wall is capable of accommodating the minor increase." The phrase "the minor increase" in the above sentence is unclear to the staff. Clarify what the source of the "minor increase" is and explain why the shear in the pilaster does not need to be evaluated.	1) Clarify what the source of the "minor increase" is and provide an explanation for how the design is adequate. The "minor increase" referred to in FSAR Section 3B.2.3.3 pertains to the shear load in the pilaster stems (the 5 foot horizontal concrete projections beyond the exterior walls). At the top of each of the four exterior RXB walls, the total lateral pilaster stem load parallel to the wall is less than 1% of the total wall in-plane shear capacity. Therefore, this load does not need to be evaluated. To provide clarification, this sentence in the FSAR will be revised to state that "the pilaster stem shear in the weak axis direction, parallel to the wall, does not need to be evaluated, because the in-plane capacity of the wall is capable of accommodating the minor increase in the	3/2/2018

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				in-plane shear loading from the pilaster stems.”	
5	9254	03.07.02-33	The staff finds that the applicant has not demonstrated that an eccentricity of 5% of the building dimension is equivalent to a 5% increase in the elemental horizontal forces. Provide additional information that provides the requested technical justification to demonstrate the equivalency to the DSRS methodology or conservatism in the method used by the applicant. Compliance with the DSRS is not a requirement; however, the applicant should identify differences between the analytical methods used for its design and the DSRS acceptance criteria and evaluate the technical acceptability of its methods. The applicant may choose to use a smaller model to illustrate the comparison of the results from the two approaches.	1) Provide additional information that provides the requested technical justification to demonstrate the equivalency to the DSRS methodology or conservatism in the method used. A calculation has been performed and will be shown in the response that includes additional information to show eccentricity of 5% of the building dimension is equivalent to a 5% increase in the elemental horizontal forces. The methodology chosen to account for accidental torsion is to increase the maximum horizontal element forces by 5% and combine them with the maximum vertical forces by means of the square root of the sum of the squares. This alternate methodology will show to be equivalent and meets the intent of DSRS 3.7.2, Acceptance Criteria 11. No FSAR updates will be provided with this response.	3/5/2018
6	9315	03.08.02-14	Per NuScale FSAR Tier 2, Section 6.3.2.3, the emergency core cooling system (ECCS) components (including valves, hydraulic lines, and actuator assemblies) are Quality Group A, Seismic Category I components designed to ASME BPV Code, Section III, Subsection NB. 1) For consistency, Table 3.2-1, Classification of Structures, Systems, and Components, should be revised to clarify the specified ECCS valves are intended to include the valves, hydraulic lines, and actuator assemblies being Quality Group A, Seismic Category I components. Per FSAR Tier 2, Section 6.3.2.2, the body of the ECCS actuator assembly serves as both a containment vessel (CNV) pressure boundary and reactor coolant pressure boundary (RCPB). General Design Criteria (GDCs) 14 and 16 require that: • The reactor coolant pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture. • Reactor containment and associated systems shall be provided to establish an essentially leak- tight barrier against the	1) The ECCS valves (RVV and RVV) and actuators (identified as the RVV Trip, RRV Trip and Reset Valves in Table 3.2-1) are already identified and specified in Table 3.2-1 as Quality Group A, Seismic Category I. Hydraulic line are not specified. FSAR Table 3.2-1 will be modified to add the hydraulic lines and valve names clarified. 2) In service inspection of the ECCS trip/reset and reset valves (actuators) nozzle to safe end and safe end to valve weld are discussed in FSAR Table 6.2-3 (RVV and RRV trip/reset nozzle to safe end weld) and Table 5.2-8 (RVV and RRV trip/reset safe end to valve weld) respectively. The nozzle to safe end weld fall under Table IWB-2500-1 (B-F) inspection requirements. The weld at this location is an NPS 4 or greater connection so the weld should have a volumetric and surface examination. Table 6.2-3 indicates only a surface examination is required. So FSAR Table 6.2-3 will be revised for this weld to identify both a volumetric and surface examinations are required. The safe end to valve weld falls under Table IWB-2500-1 (B-J) inspection	4/6/2018

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			uncontrolled release of radioactivity to the environment and to assure that the containment design conditions important to safety are not exceeded for as long as postulated accident conditions require. The ECCS actuator assembly currently protects both the CNV boundary and RCPB; therefore it is crucial that the welds and actuator assembly itself be designed to ensure and extremely low probability of leakage or failure in accordance with GDCs 14 and 16. 2) The NRC staff requests the applicant to clarify the inservice inspection (ISI) that will be performed to provide assurance of the structural integrity of the containment nozzle to safe end welds and safe end to ECCS actuator assembly welds, i.e. will they be full volumetric? 3) FSAR Tier 2, Table 6.6-1, Examination Categories, should also be revised to include this information. 4) Also, will the material the actuator assembly body is manufactured from be volumetrically examined as part of the valve fabrication requirements? 5) And what are the fabrication NDE requirements for the entire RCPB portion for this valve? Also, Per FSAR 6.3.2.2, Equipment and Component Descriptions, valve bonnet seals on each pilot valve establish the pressure boundaries internal to the valve assembly body. And in TR-1116-51962-NP “NuScale Containment Leakage Integrity Assurance Technical Report,” Section 3.2 “Containment Penetrations,” it describes a portion of the ECCS actuator pressure boundary that is accomplished by a bolted enclosure (body-to-bonnet) with a dual metal o-ring seal. In generic technical specifications (TS) Subsection 3.4.5, "RCS Operational LEAKAGE," LCO 3.4.5 states that RCS operational LEAKAGE shall be limited to: a) no pressure boundary LEAKAGE, b) 0.5 gpm unidentified LEAKAGE, c) 2 gpm identified LEAKAGE from the RCS, and d) 150 gallons per day primary to secondary LEAKAGE. (6) The NRC staff requests that the applicant clarify the periodic testing and inspection provisions it will implement to ensure no leakage past the O-ring seals of the ECCS actuator pressure boundary during normal operating conditions.	requirements. The weld at this location is less than an NPS 4 so the weld should have a surface examination. Table 5.2-8 indicates no examination is required. So FSAR Table 5.2-8 will be revised for this weld to identify a surface examination is required. 3) Table 6.6-1 defines the inspection requirements for Class 2 and Class 3 componentes. The RVV and RRV trip/reset valves (actuators) are Class 1 components and their inservice inspection requirements are defined in Table 6.2-3 and Table 5.2-8 as discussed in (2) above. 4) The RVV and RRV trip/reset actuator valve are a Class 1 valve and follow the requirements of NB-2000. Per the requirement of NB-2500 the materials listed in Table 6.1-3 for RCPB valve body and bonnets are to have volumetric examination. So a volumetric exam is performed on the actuator valve RCPB components. 5) See the response to (4). 6) The o-ring seals are the body-to-bonnet seals for each ECCS trip and reset actuator valve that are located on the exterior of the CNV. These seals form a containment and reactor coolant pressure boundary. These seals will be Appendix J Type B as-found tested each refueling outage. A separate as-left test will only be performed if (1) the as-found is unsatisfactory, or (2) an activity was performed during the outage that could have affected leakage integrity. These seals are subject to the leakage criteria of LCO 3.4.5 and part of the reactor coolant pressure boundary leakage verification performed via SR 3.4.5.1. 7) Any leakage past the trip and reset valve seals would be both unidentified RCS leakage (LCO 3.4.5.b) and containment leakage (Appendix J Type B). Any leakage from the ECCS main valves would be unidentified RCS leakage (LCO 3.4.5.b). RCS leakage is	

			(7) Also, explain how LCO 3.4.5 limits a), b), and c) would apply to leakage past the ECCS actuator O-ring seals or through the valve body. (8) Explain how such RCS leakage outside of containment would be detected, identified, and quantified during operation." (9) Were such leakage to occur without being identified but within the limit of LCO 3.4.5, what would the possible consequences be at the onset of an event?	verified periodically by SR 3.4.5.1. 8) SR 3.4.5.1 verifies RCS operational leakage is within limits by performance of a RCS water inventory balance. This inventory includes leakage both inside and outside containment. This result can be compared with containment evacuation system leakage to determine the source of the leakage (inside/outside containment). 9) SR 3.4.5.1 is performed every 72 hours. Any leakage inside the containment vessel will be catagorized as unidentified. Any leakage through the trip or reset valve o-rings would also be unidentified and enter the ultimate heat sink. This leakage would be ≤ 0.5 gpm (unidentified leakage limit). However, this amount of leakage would likely fail the Appendix J Type B leakage test. The Type B test is performed at peak containment accident pressue (Pa = 951 psia), which is less that RCS operating pressure; however, this test is satifactory to ensure this seal will perform as designed, because (1) these valves form the smallest Type B seals in the owner's Appendix J program and will have the most restrictive leakage limits, (2) the test medium is gas (air or nitrogen), and (3) the acceptance leakage criteria of the Type B test for these seals is more rigorous than the RCS operational leakage check prior to plant startup. This pressure boundary will still be tested periodically as part of SR 3.4.5.1. "	
7	8936	03.07.02-10	On Page 3A-1 of the DCD, the staff noted that a detailed dynamic Analysis Models of the NPM subsystem is performed using a more detailed NPM model and the input time histories obtained from the SSI Analysis Models of the reactor building which included a simplified NPM to account for the coupling of NPMs and the reactor building. The applicant is requested to provide, at the NPM upper support and the bottom support skirt interface locations with the RXB, a comparison of the seismic demand (forces and moments) obtained from the SSI Analysis Models of the RXB and the detailed NPM 3D Analysis Models. The applicant should also explain any significant	NuScale will provide, in a RAI response, a comparison of seismic demand forces at the NPM upper support and the bottom support skirt interface between the SSI analysis model using the simplified NPM beam model and the 3D detailed ANSYS model of the NPM bay. Significant differences between the two models will be identified and the design demand/capacity ratios will be presented to show the NPM support design is conservative. To support the response, the following technical approach will be taken: 1. Run a set of parametric analyses using	4/20/2018

			differences and confirm that the loads used for the NPM support design is conservative.	three case conditions (cracked, uncracked and reduced stiffness), at two NPM locations (module 1 and 6) to provide a sampling of results for load conditions which generally bound the design demands. 2. Prepare a summary report which provides a comparison of the reaction forces at the NPM upper support and bottom support skirt between the SSI NPM beam model and the detailed NPM 3D model. Clarify any significant differences between simplified beam model used in SSI analyses and the 3D detailed model. Provide design demand/capacity ratios from results to show NPM support design is conservative in RAI response. The results of the parametric studies will be added to the technical report, TR-0916-51502, referenced in FSAR Appendix 3A.	
8	8932	03.07.02-4	To discuss the adequacy of 7P Extended Subtraction Method (ESM) model, the applicant provided 7P versus 9P ISRS comparisons for the Capitola time histories in Figures 3.7.2-8 to10. However, the FSAR does not provide a comparison of transfer functions for the 7P and 9P models. The review of transfer functions is essential to ensure that the numerical implementation of the SSI analysis methods is acceptable and consistent with the guidance in DSRS Section 3.7.2. The staff believes that 7P vs 9P ESM comparison captures only an “incremental” enhancement between the two models. The adequacy of an ESM model should be established against the direct method (DM). Therefore, in addition to a comparison of the 7P and 9P ESM models, the applicant is requested to provide a comparison of the transfer functions for the 7P ESM and the DM models at selected nodes of the critical sections or, provide justification for why a 7P vs 9P comparison is sufficient and acceptable.	<u>7P vs. 9P comparison</u> The comparison between the results of the 7P and 9P models will be extended to include Transfer functions (TF) at the three selected locations and out-of-plane bending moments along the shell elements at the middle of the roof, which is the area that exhibits the highest ISRS. For this comparison, the RXB model with cracked concrete and 4% material damping is analyzed with Soil Types 7 and 11. Also, ISRS and Out-of-plane bending moments are the average of five CSDRS-compatible input motion results. TF will be reviewed and spurious spikes identified. The use of the ESM would normally shift the frequencies of the spurious spikes to the high frequency range. The frequency range that is minimally affected by the spurious spikes will be identified. In agreement with DSRS Section 3.7.2, it will be verified that the frequency content of the input motion that is important to the SSI analysis lies within this range. Any differences in TF between the 7P and 9P models will ultimately be evaluated by comparing the results used for design; that is, by comparing the ISRS and bending moments at the locations mentioned above. If the differences in result quantities are below 10%, then the 7P results are considered adequate. <u>ESM vs. DM comparison</u>	4/30/2018

Commented [A6]: Provide a summary markups in the FSAR 3.7.2 followed by a reference to the TR.

Commented [A7]: The applicant is requested to confirm if the TF mentioned hereinafter refers to the “acceleration” TF; if not, please provide specific qualifier before the word TF.

				a) RXB The adequacy of the ESM will also be established by a direct comparison between the results obtained using the 7P ESM and those obtained using the direct method (DM). Because the number of interaction nodes of the RXB model required for the DM exceeds the capability of SASSI2010, a reduced-size model is used, as allowed by guidance in DSRS Section 3.7.2. This reduced-size model corresponds to the north (+Y) half of the RXB, analyzed for: Soil Type 7, which is the controlling case for the majority of structural responses Cracked concrete condition with 4% damping Because the RXB is not 100% symmetric along the X (north-south) axis, for direct comparison, a new 7P ESM model is created for the north half of the building. The following responses are compared: 1. TF and ISRS at multiple critical locations including: basemat, RXM lug supports, exterior walls, pool walls, and slabs at different elevations including the center of roof. 2. Soil pressure on north wall at different elevations 3. Forces and moments in different structural elements including: exterior walls, basemat, north pool wall, roof, and pilasters. 4. Relative displacement at multiple locations including floor at different elevations, exterior walls, pool walls, and roof. b) CRB For the CRB, the interaction nodes are within the limits of SASSI2010, therefore, the full model is used for the DM. The CRB DM model will be analyzed for Soil Type 7, cracked concrete with 4% damping, and five CSDRS-compatible input motions. The responses to compare against the 7P model are: TF and ISRS at multiple critical locations including: basemat, exterior walls, and roof. TF will be reviewed and spurious spikes identified. Any differences in TF between the 7P ESM and DM models will ultimately be evaluated by comparing the results used for design; that is, ISR, forces, and/or moments. If the differences in result quantities are below 10%, then the 7P results are considered adequate.	

Commented [A8]: Please add Reactor Building Crane (RBC) support locations to the list here.

				FSAR Section 3.7.2.1.1.3, **Benchmarking**, will be expanded to include a summary of these studies	
9	8971	03.08.04-14	FSAR Section 3.8.4.3.3 describes lateral soil pressures, including dynamic soil pressures corresponding to SSI and SSSI analyses, applicable to the embedded exterior walls of the buildings. The staff request the applicant to clarify whether these pressures are based on the envelope of all SSI and SSSI analysis cases. Also the staff notes that while FSAR Section 3.8.4.3.3 describes the consideration of the aforementioned lateral soil pressures as part of the design loads for the embedded exterior walls, the magnitude of such loads was not provided in the FSAR. The applicant is requested to provide in the FSAR the pressure distributions with depth of the bounding dynamic soil pressures considered in the design of the embedded exterior walls of the buildings.	A note will be added to FSAR Section 3.8.4.3.3 to clarify that seismic soil pressures on the embedded exterior walls of the RXB and CRB are the envelope of all SSI and SSSI analysis cases. The process is described in FSAR Section 3.7.2.4.1, for combining SASSI results for design. These seismic pressures produce forces and moments on the shell elements comprising the exterior walls of the buildings which are used in their design. FSAR Section 3.8.4.3.3 will be updated to include plots showing pressure distributions of the bounding dynamic soil pressures on the embedded walls for both RXB and CRB.	4/30/2018
10	8932	03.07.02-6	a. DSRS 3.7.2 provides guidance that effects of potential separation or loss of contact between the structure and the soil during the earthquake should be considered in SSI analysis. On Page 3.7-23 of the FSAR, in the second paragraph from the bottom, the applicant states, "To model the soil separation, the Young's modulus of the backfill elements down to a depth of 25' (the top four layers of backfill elements) was decreased by a factor of 100." The applicant is requested to provide a basis for 25 ft of separation depth. Also, please clarify if the modulus reduction by a factor of 100 applies only to the backfill elements interfacing with the exterior walls or to all the backfill elements outside the exterior walls. b. On Page 3.7-23 of the FSAR, in the bottom paragraph, the applicant states, "Soil separation has negligible effect on the response of the structure. The primary point of comparison is at the NPM. The study showed that the maximum reaction force at the base of the NPMs decreased by approximately 5 percent, and the maximum reaction force at the NPM lug restraints decreased by more than 15 percent." The applicant is requested to provide information on soil separation effect on computed transfer functions and seismic demands (forces, ISRS) at critical section locations and external walls. Please provide comparison plots for results between the intact and soil-separated cases. When soil-	a. A basis for the 25 ft of separation depth will be provided along with clarification regarding the modulus reduction factor. b. Consistent with ASCE 4-16, Section 5.1.9, soil separation is considered by neglecting the soil along the upper 25ft of the RXB embedment (i.e., the Young's modulus of the backfill was factored by 1/100). SSI analysis is performed to the RXB for Soil Type 7 with cracked concrete properties and 7% concrete material damping. Soil Type 7 is used because it is the case that produced the highest ISRS and forces and moments at the majority of locations. The following responses are compared between the intact and soil-separated cases: 1. Forces at the RXM lug supports 2. ISRS at several locations including basemat edges, roof, pool floor and exterior walls. 3. Transfer functions at the same ISRS locations 4. Maximum shears and moments in all four exterior walls 5. Soil pressures in all four exterior walls Five CSDRS-compatible input motions are used to obtain structural responses, whereas Capitola CSDRS-compatible input motion is used for ISRS. Results show that demand forces and moments due to soil separation effects investigated above are within the design force and moment	5/31/2018

Commented [A9]: Clarify whether the static soil pressures (including hydrostatic, effective, and surcharge) are similarly addressed in the design demands obtained from SAP2000 and provide the description in the FSAR for both the static and dynamic soil pressures.

Commented [A10]: The response to RAI, 9049, Question 2.5.4-3 provided markups to FSAR Section 3.8.4 to address the static and total soil pressures and overturning moment on the below grade walls for the RXB. The applicant is requested to update the total soil pressures and overturning moment as necessary to include the dynamic soil pressures. Also, provide the static and total soil pressures and overturning moments for the CRB.

Commented [A11]: Since the development of design basis ISRS is based on 4% structural damping (FSAR 3.7.2.5), it is not clear how would the ISRS comparison be performed when the SSI analysis for the soil separation case used a damping level of 7% structural damping. The plan should reflect the action plan for addressing this issue. In addition, a comparison of Seismic demand at the Reactor Building Crane (RBC) support locations should be included in the plan.

			separation results in increased seismic demands, such increased demands should be taken into account in establishing the design basis seismic demands. c.The staff notes that a soil-separation study was conducted for the RXB but not for the CRB. The applicant is requested to provide a technical justification for not conducting a similar study for the CRB.	capacities. c. Additional analyses on soil separation for the CRB will be conducted as described above. Similar results will be obtained. FSAR Section 3.7.2.1.1.3, **Soil Separation**, will be expanded to include a summary of these studies and representative plots comparing results.	
11	8838	03.08.04-1	Describe the method/mechanism for restraining a bioshield mounted on an adjacent bioshield and restraining the upper CNV on the module inspection rack during the refueling operations. Further, provide analysis and design criteria (consistent with DSRS Section 3.7.2.II.8) to ensure no adverse interactions occur between the seismic Category II bioshields and inspection racks with adjacent seismic Category I SSCs, during refueling operations (and during the transport of new modules, as applicable).	1) The analysis to determine whether bioshield failure under SSE conditions could impair the integrity of seismic Category I SSCs, or result in incapacitating injury to control room occupants will be evaluated in accordance with DSRS Section 3.7.2.II.8. 2) The method/mechanism for restraining a bioshield mounted on an adjacent bioshield and restraining the upper CNV on the module inspection rack during the refueling operations will be clarified. FSAR Section 3.8.4 will be updated in accordance with DSRS Section 3.7.2.II.8.	7/10/2018
12	9309	03.08.04-37	In its response to RAI 8971, Question 03.08.04-12, the applicant indicated that the jet impingement, pipe break reaction, and missile impact loads are to be addressed by the COL applicant as per COL items 3.6- 2 and COL item 3.6-3. Based on the applicant's response, it is not clear to the staff what provisions have been incorporated in the current design to accommodate the aforementioned loads that will be established by the COL applicant and are to be combined with other loads as per Load Combinations 13 and 17 in FSAR Tables 3.8.4-1 and 3.8.4-2, respectively. Therefore, the staff request the applicant to provide the technical basis that demonstrate the adequacy of the RXB to withstand the demands from Load Combinations 13 and 17. Additionally, the staff requests the applicant to clarify the locations in the RXB where these loads are expected to occur and address the comparison of the site-specific loadings (as per load combinations 13 and 17) with the standard design loadings in the existing COL item 3.8-2 or a new COL item. Further, the staff request the applicant to update the FSAR markups proposed in its response to RAI 8971, Question 03.08.04-12, as applicable.	1) Provide the technical basis that demonstrates the adequacy of the RXB to withstand the demands from Load Combinations 13 and 17 2) Provide clarification regarding the locations in the RXB where respective loads are expected to occur and address the comparison of the site-specific loadings with the standard design loadings as in the existing COL item 3.8-2. The following approach will be taken to address the above information: Describe preliminary locations of high energy pipe locations in the building Evaluate pipe break and describe mass and energy ventilation strategy Show that for representative areas that the structural elements are adequate. Possible changes to DCA sections 3.8.4.3.18,19 and 20.	8/24/2018
13	8935	03.07.02-23	DSRS Section 3.7.2 provides guidance that, for soil-structure interaction (SSI) analysis for	Kinematic interaction does not apply to SSI analysis with SASSI. Sidewall impedance is	8/30/2018

Commented [A12]: The plan for items 2 and 3 in question 3.8.4-1 is missing. Please provide plan.

Commented [A13]: Describe in the FSAR the static and dynamic analysis methods used for the bioshield. Describe the applicable design codes and standards. Describe the applicable design loads for the bioshield. Provide the magnitude of the applicable static, seismic, pressure, and temperature loads. Provide D/C ratios for the structural components of the bioshield.

Commented [A14]: Provide FSAR markups and figures addressing design descriptions (e.g. dimensions, material properties, reinforcement details, anchors, welds, etc.).

Commented [A15]: Provide the magnitude of the resulting or assumed (with description of technical basis for assumption) for jet impingement, pipe break reaction, and missile impact loads.

Commented [A16]: Provide D/C ratios for the representative areas.

Commented [A17]: Also address changes in FSAR Section 3.6, 3.8.4.8 (and other 3.8.4 subsections as applicable), Appendix 3B, and other chapter 3 sections as applicable.

Commented [A18]: The staff understands that kinematic interaction is an important phenomenon to consider in SSI analysis, particularly for deeply embedded structures. The applicant is requested to clarify what this statement means or signifies.

			deeply embedded structures, proper consideration should be given to uncertainties associated with kinematic interaction, non-vertically propagating shear waves, sidewall impedance calculation, and other effects such as the development of gaps between the soil and structure specifically for strong-motion earthquakes. For non-vertically propagating shear waves, a sensitivity evaluation can be performed to determine whether this is an important effect to be included in the SSI analysis. Staff has not been able to identify how the applicant has considered these uncertainties associated with SSI of deeply embedded structures in the seismic analysis of NuScale Category I SSCs. Provide an explanation for what analyses the applicant has performed and how these uncertainties have been considered.	included in the impedance matrix of the excavated soil calculated by SASSI. Gaps between the soil and structure are covered under the Soil Separation studies performed and included in the FSAR Section 3.7.2.1.1.3. Regarding non-vertically propagating shear waves, the following approach will be taken: a. The angle incidence for the study will be determined based on the apparent wave velocity commonly used in practice. ASCE 4-16 Section 7.1 and its commentary provide the information for typical range of apparent wave velocity. Representative range of apparent wave velocity are identified from 2 km/sec to 5 km/sec. In Section 7.1, a conservative value of 2 km/sec (6,600 ft/sec) is recommended for seismic analysis underground pipes and conduits. b. For the purpose of sensitivity analysis, we plan to perform additional SSI analysis of the 3D F.E. model of RXB for three apparent wave velocity values of 2 km/sec, 3 km/sec and 5 km/sec. In SASSI formulation, apparent wave velocity can be used to determine the angel of incidence using the velocity of the half space soil layer in the site profile. The angle of incidence is defined from vertical axis in the half space. The angle of incidence changes as the wave propagates upward in the upper layers (Snell's law). c. For the proposed study, soil profile type 7 will be used. The reason for this choice is that the velocity of the soil layers and the half space are close and the change in the angle of incidence due to upward wave propagation will be small. d. The results of analysis for the three cases will be compared with the results for the vertically propagating waves in terms of ISRS at multiple locations on the exterior and interior walls to assess the impact of inclined waves on the response. In addition, seismic loads and seismic soil pressure or selected out of plane forces of the exterior walls at few key locations will be obtained and compared. A summary of this study will be included at the end of FSAR Section 3.7.2.1.1.3, under the title Non-vertically Propagating Shear Waves.	

14	8964	03.08.05-2	In FSAR Tier 2, Section 3.8.5.6.7, "Basemat Soil Pressures along Basemat Edges (Toe Pressures)," the applicant performed analyses to determine the edge bearing pressures (or toe pressures) along the edges of the seismic Category I structure basemats (RXB and CRB). In FSAR Tier 2, Section 3.8.5.5.5 "Settlement Approach," the applicant considered a condition of the soil stiffnesses that are further reduced by 50 percent to amplify the effect of settlements. FSAR Tier 2, Section 3.8.5.6.7, "Basemat Soil Pressures along Basemat Edges (Toe Pressures)," the applicant performed analyses to determine the edge bearing pressures (or toe pressures) along the edges of the seismic Category I structure basemats (RXB and CRB). In FSAR Tier 2, Section 3.8.5.5.5 "Settlement Approach," the applicant considered a condition of the soil stiffnesses that are further reduced by 50 percent to amplify the effect of settlements. Therefore, provide information on associated settlements due to soft soil stiffnesses along the edges of the seismic Category I structure.	1) Provide information on associated settlements due to soft soil stiffnesses along the edges of the seismic Category 1 structure The triple building model report will be revised to include toe settlements and toe bearing pressures determined from the combined results of the SASSI2010 and SAP2000 models. The soil stiffness is reduced by 50% to amplify the settlements. The results envelope cracked and uncracked concrete conditions. Forces and moments in the basemat due to toe bearing pressures will be determined and compared with ACI 349 allowables. Settlement values will be compared with NuScale-defined limits. FSAR Section 3.8.5 will be updated, as necessary to incorporate information from the revised report.	8/30/2018
15	8971	03.08.04-13	10 CFR 50, Appendix A, GDC 1, 2, and 4, provide requirements to be met by SSC important to safety. In accordance with these requirements, DSRS Section 3.8.4 provides review guidance pertaining to the design of seismic Category I structures, other than the containment. Consistent with DSRS Section 3.8.4, the staff reviews loads and loading combinations. FSAR Section 3.8.4.4.1 indicates that an ANSYS model was created to evaluate the effects of thermal loads on the structure. Further, FSAR Section 3.8.4.5 indicates that load combination 10 from Table 3.8.4-1 has been determined to be the controlling load combination. The staff request the applicant to provide the following information. a)Magnitude of the bounding forces and moments profiles for walls and basemat resulting from thermal loads, To and Ta. Clarify whether such values were used in the load combinations 10 and 13 in Tables 3.8.4-1. b)Describe how load combination 10 was determined to be the controlling load combination instead of load combination 13, and provide an example of how the loads were combined.	1) Provide the magnitude of the bounding forces and moments profiles for walls and basemat 2) Describe how load combination 10 was determined to be the controlling load combination instead of load combination 13 The following approach will be taken to address the above information: - The magnitude of the thermal forces and moments will be extracted from the finite element models. - Clarify from this extracted information consideration in the load combinations the magnitude of the bounding forces and moments profiles for walls and basemat resulting from thermal loads. - Review the determination of the controlling load combination, including an example of how the loads were combined. - Revise FSAR Section 3.8.4 text and tables 3.8.4-1.	8/30/2018
16	8933	03.07.	In FSAR Section 3.7.2.1.2.1, the staff noted	NuScale will provide, in a RAI response,	10/31/

Commented [A19]: Describe in the FSAR the determination of the controlling load combination and provide an example of how the loads were combined.

		02-16	that the dry dock is assumed to be full of water and part of the UHS in the seismic analysis. The nominal water level is at EL. 94 ft. In FSAR Section 9.1.3, the staff also noted that the dry dock can be drained partially or completely to support plant operations. In FSAR Section 9.1.3.3.5, the staff further noted that a failure of the dry dock gate while the dry dock is empty could result in a decrease in water level at the UHS pool by about 12 ft. Since the dry dock contains a large body of water, draining of a large mass of water could affect the dynamic characteristics of the SASSI and ANSYS models thereby potentially affecting the seismic demand based on full dry dock assumption. Provide a technical basis for not considering different water level conditions for the dry dock in the seismic analysis. In addition, the applicant should address the effect of potential variation in water level of the UHS on the seismic analysis of the RXB and NPM including the analyses conducted in FSAR 3.7.2.9.1 to address the effect of operation with less than the full complements of NPMs.	further clarification of the operating band level for the RXB pool water. In addition, a description of the dry dock gate analysis and design criteria will be provided to ensure that no adverse seismic interaction occurs between the dry dock gate and adjacent SSCs. The maximum design loads for the dry dock gate occur when the pool is full. Technical justification will be provided through a parametric study comparing design forces with an empty dry dock for confirmation to show that the dry dock gate has been designed to the bounding load case and will not fail under a safe shutdown earthquake (SSE). With this, NuScale does not believe it is necessary to account for a 12 foot drop in the UHS pool water level in the dynamic analyses. To support the response: 1. Develop SAP2000 and SASSI model with the dry dock empty of its water, and show that the results on the foundation and walls are bounded by the full pool. Discuss in an RAI response by ratio of mass that would be reduced that the overall dynamic characteristics of the building would not be significantly different 2. Clarify with the NRC that we only have a 1 foot operating band of water level, and not the 12 feet noted in Chapter 9, and thus there really is no effect of the variation of water level 3. Provide the details of the dry dock gate calculation – that it's designed to the full safe shutdown earthquake with water on one side, and empty on the other and is adequate. The information will be provided in an RAI response and FSAR Tier 2 Section 3.7.2 will be updated. Tier 2 Section 3.7.2.1.2.1 of the FSAR will be supplemented with a technical justification summary for the design assumption of a pool full of water being the bounding design condition for the dry dock gate. Potential variations of the UHS pool will not be considered as a design condition for the NuScale Power Plant.	2018
17	8932	03.07.02-5	10 CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion associated with the Safe Shutdown Earthquake	NuScale will provide, through the RAI response, additional transfer function plots at key nodes in critical sections within the RXB and CRB. The plots will be supplemented with a discussion of potential	11/29/2018

Commented [A20]: Please confirm that the action plan includes the following elements:
1. Description of the SSI analysis with the empty dry dock including the parameters (e.g., cracked and/or uncracked model, structural damping values and the soil properties, as well as the input spectra (CSDRS, CSDRS-HF)) selected for the study and their basis.
2. In addition to the foundation and walls, description of the other key locations where the seismic and equipment demand including the ISRS are compared to ensure that the seismic demand used for the design bounds the demand obtained from the full pool analysis with the dry dock empty.
3. Comparison of the transfer functions at the selected locations
4. Markup of Appropriate FSAR Sections (e.g., 3.7, 3.8, 9.1.3, etc.)

Commented [A21]:
Describe in the FSAR the applicable design codes and standards and the applicable design loads (including FSI effects amongst other as applicable) and respective magnitudes. Provide D/C ratios.

Provide FSAR markups and figures addressing design descriptions (e.g. dimensions, material properties, anchorage, welds, etc.).

			(SSE) through design, testing, or qualification methods. On Page 3.7-22 of the FSAR, in the fourth paragraph, the applicant states, "However due to the size and complexity of these models it is not practical to review transfer functions at all the nodes in the models." The staff views that the applicant may not need to review transfer functions (TFs) at all nodes; however, the staff views that TFs at key locations should be reviewed to ensure the adequacy of the SSI models and methodologies implemented in the seismic analyses. Therefore, the applicant is requested to provide information on TFs (in plots) at selected nodes of the critical sections and other important locations in the RXB and CRB. The plots should be inspected whether spurious spikes in the TFs are present within the frequency range of interest to the SSI analysis; and, if spikes are present, the applicant should discuss their potential effects on computed seismic demands.	effects of spurious spikes where applicable. The transfer functions will be extracted from a sampling of the SSI analyses that have been used for design of the plant: 1. Revise CRB and RXB SSI ISRS calculations to include additional transfer function data at critical node locations. 2. TFs at those key locations will be reviewed to ensure the adequacy of the SSI models and methodologies implemented in the seismic analyses. 3. The new plots will be inspected whether spurious spikes in the TFs are present within the frequency range of interest to the SSI analysis; and, if spikes are present, their potential effects on computed seismic demands will be investigated. Tier 2 Section 3.7.2.1.1.3 of the FSAR will be updated to include additional descriptions of the transfer functions at critical locations and provide TF plots are critical locations. Any spikes observed in the frequency range of interest will be further explained.	
18	8935	03.07.02-26	a.In FSAR Subsection 3.7.2.5.2, the applicant indicates that the ISRS from the triple building model were considered for the design of SSCs in the RXB but not for the CRB." It is expected that the structure-soil-structure interaction (SSSI) effect would be more pronounced on a lighter building (CRB) than a neighboring heavier building (RXB). The applicant is requested to provide justification for not considering the ISRS from the triple building model for the design of SSCs in the CRB. b. Figures 3.7.2-106 and 107 in the FSAR present the Reactor Building ISRS for floor at EL 24' and EL 25', respectively, which indicates noticeable difference in ISRS (both in shape and amplitude) for an elevation difference of only 1 foot. The applicant is requested to discuss the factors contributing to this observed difference.	1) The ISRS from the triple building model for the design of SSCs in the CRB will be provided. ISRS will be developed in accordance with RG. 1.1.2.2 "Development of Floor Design Response Spectra for Seismic Design of Floor-Supported Equipment or Components" and the NuScale Seismic Design Criteria. FSAR Section 3.7.2 will be updated to include details on the ISRS. 2) The approach to be used is the same process used for the RXB. 3) A discussion of the factors contributing to the difference in the RXB ISRS will be provided.	11/29/2018
19	8933	03.07-02-17	b. On Page 3.7-25 of the FSAR, in the sixth paragraph, the applicant states, "The rigid springs have a zero length and have a stiffness value large enough to simulate rigid connection. The large stiffness used is arbitrarily chosen to be ten billion lbs per inch, or 1010 lbs/inch, in the three global directions." For the spring to be modeled as a rigid spring, the value of its spring constant should be	NuScale will povide, through the RAI response, a sensitivity study with summarized results to support the selection of the large 10e10 lbs/inch stiffness value used for the rigid springs. An alternate sensitivity study will be presented to justify the use of the rigid springs in the analyses. The goal of these rigid springs is to connect the soil nodes to	12/20/2018

Commented [A22]: The applicant is requested to be more specific in its approach to addressing any spurious spikes identified in the TFs.

Commented [A23]: Missing the plan for items a and c in question 3.7.2-17. Please provide plan.

			sufficiently larger than the stiffness of the structural element (basemat) to which it is attached. The applicant is requested to confirm the adequacy of the number (1010 lbs/inch) chosen for the spring constant by comparing it to the stiffness of the adjacent basemat element or through an appropriate sensitivity run using a number at least an order of magnitude different.	the structural element nodes without compromising the soil- structure interaction and building response. Therefore, to demonstrate the validity of the element stiffness, a comparison of relative displacements will be provided between the two nodes of the spring element (I and J) to demonstrate the rigid behavior using the 10e10 lbs/inch stiffness: 1. Using a sampling of SSI analysis cases, extract the relative displacements between the I and J nodes of the rigid spring elements. 2. Clarify that the differential displacement at I and j nodes of rigid link is very small (10-5 in), demonstrating rigid behavior. 3. Include results of relative displacements and justification of stiffness in the seismic SSI calculations. Section 3.7.2.1.2.1 will be supplemented to summarize the conclusions of the study and provide technical justification confirming the 10e10 lbs/inch stiffness property simulates a rigid connection.	
20	8935	03.07.02-25	10 CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion associated with the Safe Shutdown Earthquake (SSE) through design, testing, or qualification methods. Tables 3.7.2-23, 24 and 25 in the FSAR respectively provide SSI analysis results for one particular "example" shell, beam, and solid element, respectively. However, analysis results at other key locations are not provided. The applicant is requested to provide the design-basis seismic demands (e.g., forces, moments, soil pressures, accelerations, displacements, ISRS), at all applicable critical section locations of the RXB and CRB, that are used in structural design evaluations in FSAR Sections 3.8.4 and 3.8.5.	1) Provide the design-basis seismic demands, at all applicable critical section locations of the RXB and CRB. The forces, displacements, soil pressures, and ISRS will be computed according to NRC RG's, SRP's and DSRS (using the approaches outlined in FSAR Section 3.8.4 and 3.8.5). ACI 349-06 provides acceptance criteria for displacements in concrete structures. 2) Tables 3.7.2-23, 24 and 25 will be revised or a new table will be provided.	12/20/2018
21	8963	03.08.05-6	Section 3.8.4.1, the basemat reinforcement pattern of the foundation of RXB. However, the applicant did not provide sufficient information for the design assessments, boundary conditions for each foundation model, settlement evaluation and associated figures. Provide for the RXB basemat: - design assessments-should include: the	NuScale will provide, through the RAI response, additional information to supplement the design of the RXB basemat. The information will be tabulated to support design assessments, and will include design capacity, forces and moments at critical sections. In addition, a full description of analysis and boundary conditions will be	12/20/2018

			capacity of sections, design checks, etc. - boundary conditions for each foundation model -should include: stiffness types and parameter throughout the embedded portion of the RXB for each type of model (standalone and combined) – SASSI2010, SAP2000, and ANSYS -- - settlement evaluations and figures showing reinforcement patters for (a) the entire RXB basemat, (b) intersections between walls & the RXB basemat, and (c) intersections between pilasters & the RXB basemat. Settlement evaluation should include following types of settlements: (1) Maximum vertical settlements, (2) tilt settlement, (3) differential settlement between structures and (4) angular distortion.	provided for each model to demonstrate compliance with DSRS Section 3.8.5.II.4.N. To support the response: 1. Triple Building Differential Settlement calculation will be revised to include the capacity of sections, forces & moments at critical locations, settlement evaluation, and additional boundary conditions. 2. The additional information will be reviewed, organized and tabulated to support design assessments. Tier 2 Section 3.8.5.4.1 of the FSAR will be supplemented with additional descriptions of the basemat foundation analyses including boundary conditions and settlement evaluations. The additional information provided in tabular format for the design assessments of the foundations will be added to Appendix 3B of the FSAR.	
22	8971	03.08.04-11	While the magnitude of bounding demand forces and moments were provided for some critical sections (e.g. FSAR Tables 3B-36 to 3B-38), the FSAR did not provide the magnitudes of bounding demand forces and moments for all critical sections identified for the RXB and CRB. Provide in the FSAR the magnitude of bounding demand forces and moments for all critical sections, with a breakdown of seismic and static forces and moments. Additionally, provide a numerical example that demonstrates how the direction of dynamic forces and moments is addressed in the load combinations as to ensure that the direction that is most adverse in a load combination has been considered as indicated in FSAR Section 3B.1.1.2.	Critical sections are defined as parts of the structure that: (1) perform a safety-critical function, (2) are subjected to large stress demands, (3) are considered difficult to design or construct, or (4) are considered to be representative of the structural design. These critical sections are listed in Appendix 3B of the FSAR. Static and dynamic structural responses obtained from SAP2000 and SASSI2010 analyses will be utilized to develop demand forces and moments such as static compression (negative) or tension (positive) membrane forces for walls and slabs. Results of the SASSI2010 soil-structure interaction analysis which is used to analyze seismic loads will contain dynamic force and moments which are dependent of the direction of the seismic load applied to the structure. The direction resulting in most adverse load combination is considered for structural design. This information will be used to revise the calculations and present the magnitudes of bounding demand forces and moments for all critical sections. To show how the effect of the direction of the seismic loads is considered in the design, an example will be provided that demonstrates that the most adverse direction in a load combination has been considered. In addition, a breakdown of static and seismic forces will be prepared and presented. Finally, FSAR Section 3.8.4 and Appendix 3B will be revised to	12/20/2018

Commented [A24]: Clarify whether this process has already been performed in support of the design results presented in FSAR Appendix 3B.

Commented [A25]: Clarify whether the current calculation is based on the bounding demand forces and moments for all critical sections. If not, describe what are they based on as applicable.

				include the details of the above research. In summary, Revise the calculations to include the magnitudes of bounding demand forces and moments for all critical sections; Include a breakdown of seismic and static forces and moments; Develop an example to demonstrate that the most adverse direction in a load combination has been considered; and Update the FSAR Section 3.8.4 and Appendix 3B and include the results of the above research.	
23	8974	03.08.04-20	10 CFR 50, Appendix A, GDC 1, 2, and 4 provides requirements to be met by SSC important to safety. In accordance with these requirements, DSRS Section 3.8.4 provides review guidance pertaining to the design of important to safety seismic Category I structures, other than the containment. Consistent with DSRS Section 3.8.4, the staff reviews, in part, loads and loading combinations. Provide the magnitude of bounding seismic design forces of the roof in the three orthogonal directions (North-South, East-West, and Vertical).	1) The magnitude of bounding seismic design forces of the roof in the three orthogonal directions will be provided, consistent with DSRS Section 3.8.4. The following approach will be taken to address the response: Revise calculations for RXB SSI and CRB SSI to add the magnitude of bounding seismic design forces of the roof in the three orthogonal directions. A table, showing the bounding forces, will be added to FSAR Section 3.8.4	12/20/2018

Commented [A26]: Clarify whether the determination of design demands has already been performed in support of the design results presented in FSAR Appendix 3B.

Commented [A27]: Clarify whether the current calculation is based on the bounding demand forces and moments for all critical sections. If not, describe what are they based on as applicable.

Commented [A28]: As per the plan for question 03.07.02-25, the seismic demands will be provided in new or revised tables in FSAR section 3.7.2. Therefore those do not have to be repeated in FSAR section 3.8.4. Please provide in FSAR Section 3.8.4 the static and total demands and a reference to the FSAR Section 3.7 tables containing the seismic demands.

Commented [A29]: Clarify whether the determination of design demands has already been performed in support of the design results presented in FSAR Appendix 3B.

Commented [A30]: Clarify whether the current calculation is based on the bounding seismic demands. If not, describe what are they based on as applicable