Appendix A
RG 1.82 Conformance Assessment

A.1 Regulatory Guide 1.82

NRC Regulatory Guide (RG) 1.82 describes acceptable methods and guidelines for evaluating the adequacy of plant design features and ECCS performance. RG 1.82 provides a framework for licensees to develop, demonstrate and implement a comprehensive response to GSI-191 resolution.

An assessment of U.S. EPR conformance to RG 1.82 has been performed. All 53 PWR-related guidance and five potentially applicable BWR guidance items were reviewed. The results of this assessment are detailed in Table A.1.

Table A.1 RG-1.82 Conformance Assessment Matrix

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C.	**REGULATORY POSITION**	
	This section states regulatory positions on design criteria, performance standards, and analysis methods that relate to PWRs (Regulatory Position 1) and BWRs (Regulatory Position 2). As stated in the Introduction to this guide, the purpose of the guidance is to identify information and methods acceptable to the NRC staff for evaluating analytical techniques and implementing regulations related to water sources for long-term cooling of both existing and future reactor systems. The guidance, to a great extent, is generic and it may go beyond the current design of some operating reactor systems.	No response necessary – Introductory Material.
1.	**PRESSURIZED WATER REACTORS**	
1.1	**Features Needed to Minimize the Potential for Loss of NPSH**	
1.1.1	**ECC Sumps, Debris Interceptors, and Debris Screens**	
1.1.1.1	A minimum of two sumps should be provided, each with sufficient capacity to service one of the redundant trains of the ECCS and CSS. Distribution of water sources and containment spray between the sumps should be considered in the calculation of boron concentration in the sumps for evaluating post-LOCA subcriticality and shutdown margins. Typically, these calculations are performed assuming minimum boron concentration and minimum dilution sources. Similar considerations should also be given in the calculation of time for Hot Leg Switchover, which is calculated assuming maximum boron concentration and a minimum of dilution sources.	The U.S. EPR IRWST has 4 sumps, one for each of the 4 ECCS pumps. The IRWST is the sole water source (≈500,000 gallons) for these pumps. Sub-criticality analyses assume minimum boron concentrations while maximum boron concentrations are assumed for hot leg switchover timing. Furthermore, dilution of the IRWST from internal sources has been evaluated. The

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		risk of dilution is considered negligible because of the amount of dilutent (≈53,000 gallons) required to achieve a significant (i.e., 10%) reduction in boron concentration is unrealistic (i.e., without going undetected).
1.1.1.2	To the extent practical, the redundant sumps should be physically separated by structural barriers from each other and from high-energy piping systems to preclude damage from LOCA, and, if within the design basis, main steam or main feedwater break consequences to the components of both sumps (e.g., trash racks, sump screens, and sump outlets) by whipping pipes or high-velocity jets of water or steam.	The IRWST is a 270° annular tank located in the space bounded by the reactor vessel support structure, the RCS loop area heavy floor (6.6 ft thick), the containment basemat, and the containment annular wall. These boundaries, in particular, the heavy floor, provide significant protection for the ECCS sumps (located on the IRWST floor); thereby precluding any post-LOCA induced damage. Hence, the U.S. EPR design eliminates the need for physically separated sumps.
1.1.1.3	The sumps should be located on the lowest floor elevation in the containment exclusive of the reactor vessel cavity to maximize the pool depth relative to the sump screens. The sump outlets should be protected by appropriately oriented (e.g., at least two vertical or nearly vertical) debris interceptors: (1) a fine inner debris screen and (2) a coarse outer trash rack to prevent large debris from reaching the debris screen. A curb should be provided upstream of the trash racks to prevent high-density debris from being swept along the floor into the sump. To be effective, the height of the curb should be appropriate for the pool flow velocities, as the debris can jump over a curb if the velocities are sufficiently high. Experiments documented in NUREG/CR-6772 and NUREG/CR-6773 have	U.S. EPR design features satisfy this guidance – weir, trash racks, retaining basket and ECCS sump strainer. ECCS sump strainer testing validates design. Also, the ECCS sumps are located on the IRWST floor, which is also the top of the containment basemat. This maximizes the pool depth relative to the sump screens and pump suction.

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	demonstrated that substantial quantities of settled debris could transport across the sump pool floor to the sump screen by sliding or tumbling.	
1.1.1.4	The floor in the vicinity of the ECC sump should slope gradually downward away from the sump to further retard floor debris transport and reduce the fraction of debris that might reach the sump screen.	NOT APPLICABLE: The U.S. EPR design does not require that the floor in the vicinity of the ECC sumps be sloped away from the sump for the following reasons: The IRWST, due to its isolated location, is not subject to heavy debris loading. The retaining baskets will intercept any debris entering from the loop area above. The ECCS sump screens have a significant amount of surface area and the effect of floor debris will be minimal. The physical attachment of the ECC sump screen to the IRWST floor will also function as a berm. All these features coupled with the very low flow velocities within the IRWST will significantly reduce the amount of floor debris that might reach the screen.
1.1.1.5	All drains from the upper regions of the containment should terminate in such a manner that direct streams of water, which may contain entrained debris, will not directly impinge on the debris interceptors or discharge in close proximity to the sump. The drains and other narrow pathways that connect compartments with	U.S. EPR design meets this guidance. Reactor Building drains that contain retained debris terminate in the retaining baskets, with the exception of a cavity drain line from the reactor cavities to the

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	potential break locations to the ECC sump should be designed to ensure that they would not become blocked by the debris; this is to ensure that water needed for an adequate NPSH margin could not be held up or diverted from the sump.	IRWST. Following a LOCA, the only water that passes through the cavity drain line to the IRWST is "condensation" from the containment atmosphere. The U.S. EPR design does not take credit for the containment spray system. Therefore, this drain line does not function as a return path for containment spray during a design basis LOCA event. The upstream opening of the cavity drain line is remote from the LOCA debris. The downstream opening of the cavity drain line does not affect the strainer operation. The cavity drain line is not considered a debris supply path to the IRWST water volume.

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1.1.1.6	The strength of the trash racks should be adequate to protect the debris screens from missiles and other large debris. Trash racks and sump screens should be capable of withstanding the loads imposed by expanding jets, missiles, the accumulation of debris, and pressure differentials caused by post-LOCA blockage under design-basis flow conditions. When evaluating impact from potential expanding jets and missiles, credit for any protection to trash racks and sump screens offered by surrounding structures or credit for remoteness of trash racks and sump screens from potential high energy sources should be justified.	The 6.6 ft thick RCS loop area heavy floor and the heavy duty trash racks that cover the floor openings prevent missiles, large debris, and expanding jets from impacting the retaining baskets or the ECC screens. The floor openings are located on the periphery of the RCS loops, thereby reducing the trash rack profile for a majority of break locations. The trash racks are designed to prevent major debris from falling through the opening into the retaining baskets. The retaining baskets and the ECC sump screens rely on the 6.6 ft thick heavy floor, the trash racks and distance for protection from jet impingement and missiles. Nevertheless, they are designed for the maximum expected debris loading and the corresponding differential pressure.
1.1.1.7	Where consistent with overall sump design and functionality, the top of the debris interceptor structures should be a solid cover plate that is designed to be fully submerged after a LOCA and completion of the ECC injection. The cover plate is intended to provide additional protection to debris interceptor structures from LOCA generated loads. However, the design should also provide means for venting of any air trapped underneath the cover.	NOT APPLICABLE: The recommended guidance is not consistent with the U.S. EPR design. The U.S. EPR trash racks perform the debris intercept function and are located on the RCS loop area floor openings. The trash racks are designed to prevent major debris from falling through the opening

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		into the retaining baskets. Therefore, a cover plate is not required. As such, the U.S. EPR design does not require venting.
1.1.1.8	The debris interceptors should be designed to withstand the inertial and hydrodynamic effects that are due to vibratory motion of a safe shutdown earthquake (SSE) following a LOCA without loss of structural integrity.	The trash racks, retaining baskets and ECC sump strainers are safety-related components and are designed to meet U.S. EPR Seismic Category I.
1.1.1.9	Materials for debris interceptors and sump screens should be selected to avoid degradation during periods of both inactivity and operation and should have a low sensitivity to such adverse effects as stress-assisted corrosion that may be induced by chemically reactive spray during LOCA conditions.	Materials of construction are consistent with those used in other systems containing borated water. Hence, the trash racks, retaining baskets, ECC sump screens are made of austenitic stainless steel. The acceptability of the material selection for post-LOCA service relative to chemical effects (i.e. sump chemistry) is part of the U.S. EPR design process and design requirements.
1.1.1.10	The debris interceptor structures should include access openings to facilitate inspection of these structures, any vortex suppressors, and the sump outlets.	U.S. EPR design provides access for IRWST component inspections.
1.1.1.11	A sump screen design (i.e., size and shape) should be chosen that will avoid the loss of NPSH from debris blockage during the period that the ECCS is required to operate in order to maintain long-term cooling or maximize the time before loss of NPSH caused by debris blockage when used with an active mitigation system (see Regulatory Position 1.1.4).	U.S. EPR ECCS sump screens are designed such that NPSH is not lost even with maximum debris loading. Their large surface area provides ample filtration area and debris build up is self-limiting on vertical surfaces due to their inverted trapezoidal shape.

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1.1.1.12	The possibility of debris-clogging flow restrictions downstream of the sump screen should be assessed to ensure adequate long term recirculation cooling, containment cooling, and containment pressure control capabilities. The size of the openings in the sump debris screen should be determined considering the flow restrictions of systems served by the ECCS sump. The potential for long thin slivers passing axially through the sump screen and then reorienting and clogging at any flow restriction downstream should be considered. Consideration should be given to the buildup of debris at downstream locations such as the following: containment spray nozzle openings, HPSI throttle valves, coolant channel openings in the core fuel assemblies, fuel assembly inlet debris screens, ECCS pump seals, bearings, and impeller running clearances. If it is determined that a sump screen with openings small enough to filter out particles of debris that are fine enough to cause damage to ECCS pump seals or bearings would be impractical, it is expected that modifications would be made to ECCS pumps or ECCS pumps would be procured that can operate long term under the probable conditions.	Assessment not included in this report.
1.1.1.13	ECC and containment spray pump suction inlets should be designed to prevent degradation of pump performance through air ingestion and other adverse hydraulic effects (e.g., circulatory flow patterns, high intake head losses).	U.S. EPR design is such that the ECCS sumps are submerged sufficiently to preclude vortex formation and air ingestion. Additionally, sump screens are provided with vortex suppressors to provide an added measure of margin against vortex formation and air ingestion.
1.1.1.14	All drains from the upper regions of the containment building, as well as floor drains, should terminate in such a manner that direct streams of water, which may contain entrained debris, will not discharge downstream of the sump screen, thereby bypassing the sump screen.	The U.S. EPR reactor building drains and similar lines terminate upstream of the sump screen, thereby precluding bypass of the ECCS sump strainers.

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1.1.1.15	Advanced strainer designs (e.g., stacked disc strainers) have demonstrated capabilities that are not provided by simple flat plate or cone-shaped strainers or screens. For example, these capabilities include built-in debris traps where debris can collect on surfaces while keeping a portion of the screen relatively free of debris. The convoluted structure of such strainer designs increases the total screen area, and these structures tend to prevent the condition referred to as the thin bed effect. It may be desirable to include these capabilities in any new sump strainer/screen designs. The performance characteristics and effectiveness of such designs should be supported by appropriate test data for any particular intended application.	NOT APPLICABLE: The U.S. EPR design employs a simple strainer concept validated by testing.
1.1.2	**Minimizing Debris -** The debris (see Regulatory Position 1.3.2) that could accumulate on the sump screen should be minimized.	No response necessary – Introductory Material
1.1.2.1	Cleanliness programs should be established to clean the containment on a regular basis, and plant procedures should be established for control and removal of foreign materials from the containment.	ADDRESSED BY COL APPLICANT: This is a programmatic requirement. Refer to U.S. EPR FSAR COL Information Item 6.3-1 (Table 1.8-2).
1.1.2.2	Insulation types (e.g., fibrous and calcium silicate) that can be sources of debris that is known to more readily transport to the sump screen and cause higher head losses may be replaced with insulations (e.g., reflective metallic insulation) that transport less readily and cause less severe head losses once deposited onto the sump screen. If insulation is replaced or otherwise removed during maintenance, abatement procedures should be established to avoid generating latent debris in the containment.	NOT APPLICABLE: This item applies to potential insulation replacement after the plant is licensed and is operating. The U.S. EPR design uses RMI for reactor coolant system piping and components. A limited amount of fibrous insulation will be permitted. As described

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		in 1.1.2.1 above, containment cleanliness is ensured programmatically.
1.1.2.3	To minimize potential debris caused by chemical reaction of the pool water with metals in the containment, exposure of bare metal surfaces (e.g., scaffolding) to containment cooling water through spray impingement or immersion should be minimized either by removal or by chemical-resistant protection (e.g., coatings or jackets).	As part of the U.S EPR GSI-191 program, chemical effects evaluations were evaluated to address the potential impact of chemical reaction with the debris sources.
1.1.3	**Instrumentation -** If relying on operator actions to mitigate the consequences of the accumulation of debris on the ECC sump screens, safety-related instrumentation that provides operators with an indication and audible warning of impending loss of NPSH for ECCS pumps should be available in the control room.	NOT APPLICABLE: U.S. EPR design does not require operator action to backflush ECC sump screens; however, a non-safety-related backflushing system is provided.
1.1.4	**Active Sump Screen System -**An active device or system (see examples in Appendix B) may be provided to prevent the accumulation of debris on a sump screen or to mitigate the consequences of accumulation of debris on a sump screen. An active system should be able to prevent debris that may block restrictions found in the systems served by the ECC pumps from entering the system. The operation of the active component or system should not adversely affect the operation of other ECC components or systems. Performance characteristics of an active sump screen system should be supported by appropriate test data that address head loss performance.	NOT APPLICABLE: The U.S. EPR design does not require operator action to backflush ECC sump screens; however, a non-safety-related backflushing system is provided.
1.1.5	**Inservice Inspection** To ensure the operability and structural integrity of the trash racks and screens, access openings are necessary to permit inspection of the ECC sump structures and outlets. Inservice inspection of racks, screens, vortex suppressors, and sump outlets, including visual examination for evidence of structural degradation or corrosion, should be performed on a	U.S. EPR design provides suitable access to trash racks, retaining baskets and sump screens. Refer to U.S. EPR Technical Specifications Surveillance Requirement 3.5.2.6.

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	regular basis at every refueling period downtime. Inspection of the ECC sump components late in the refueling period will ensure the absence of construction trash in the ECC sump area.	
1.2	**Evaluation of Alternative Water Sources -** To demonstrate that a combination of the features and actions listed above are adequate to ensure long-term cooling and that the five criteria of 10 CFR 50.46(b) will be met following a LOCA, an evaluation using the guidance and assumptions in Regulatory Position 1.3 should be conducted. If a licensee is relying on operator actions to prevent the accumulation of debris on ECC sump screens or to mitigate the consequences of the accumulation of debris on the ECC sump screens, an evaluation should be performed to ensure that the operator has adequate indications, training, time, and system capabilities to perform the necessary actions. If not covered by plant specific emergency operating procedures, procedures should be established to use alternative water sources that will be activated when unacceptable head loss renders the sump inoperable. The valves needed to align the ECCS and containment spray systems (taking suction from the recirculation sumps) with an alternative water source should be periodically inspected and maintained.	NOT APPLICABLE: U.S. EPR design does not require an alternate source of water (i.e., alternate to the water in the IRWST) to meet 10 CFR 50.46 (b) requirements following a LOCA.
1.3	**Evaluation of Long-Term Recirculation Capability -** The following techniques, assumptions, and guidance should be used in a deterministic, plant-specific evaluation to ensure that any implementation of a combination of the features and capabilities listed in Regulatory Position 1.1 are adequate to ensure the availability of a reliable water source for long-term recirculation following a LOCA. The assumptions and guidance listed below can also be used to develop test conditions for sump screens.	Informational Material

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	Evaluation and confirmation of (1) sump hydraulic performance (e.g., geometric effects, air ingestion), (2) debris effects (e.g., debris transport, interceptor blockage, head loss), and (3) the combined impact on NPSH available at the pump inlet should be performed to ensure that long-term recirculation cooling can be accomplished following a LOCA. Such an evaluation should arrive at a determination of NPSH margin calculated at the pump inlet. An assessment should also be made of the susceptibility to debris blockage of the containment drainage flow paths to the recirculation sump; this is to protect against reduction in available NPSH if substantial amounts of water are held up or diverted away from the sump. An assessment should be made of the susceptibility of the flow restrictions in the ECCS and CSS recirculation flow paths downstream of the sump screens and of the recirculation pump seal and bearing assembly design to failure from particulate ingestion and abrasive effects to protect against degradation of long-term recirculation pumping capacity.	
1.3.1	**Net Positive Suction Head of ECCS and Containment Heat Removal Pumps**	
1.3.1.1	ECC and containment heat removal systems should be designed so that sufficient available NPSH is provided to the system pumps, assuming the maximum expected temperature of pumped fluid and no increase in containment pressure from that present prior to the postulated LOCA. (See Regulatory Position 1.3.1.2.) For sump pools with temperatures less than 212°F, it is conservative to assume that the containment pressure equals the vapor pressure of the sump water. This ensures that credit is not taken for the containment pressurization during the transient. For sub-atmospheric containments, this guidance should apply after the	The U.S. EPR design does not fully conform to Section 1.3.1.1. The containment pressure is assumed to be equal to the initial containment pressure prior to the start of the accident. This fulfills the requirements of RG 1.1 and RG 1.82 that the NPSH available is evaluated without crediting any increase in pressure resulting from accident conditions at low temperatures. This

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	injection phase has terminated. For sub-atmospheric containments, prior to termination of the injection phase, NPSH analyses should include conservative predictions of the containment atmospheric pressure and sump water temperature as a function of time.	approach verifies that sufficient containment pressure is available under accident conditions. For temperatures higher than the initial saturation pressure, the containment pressure is assumed to be equal to the sump fluid vapor pressure.
1.3.1.2	For certain operating PWRs for which the design cannot be practicably altered, conformance with Regulatory Position 1.3.1.1 may not be possible. In these cases, no additional containment pressure should be included in the determination of available NPSH than is necessary to preclude pump cavitation. Calculation of available containment pressure and sump water temperature as a function of time should underestimate the expected containment pressure and overestimate the sump water temperature when determining available NPSH for this situation.	NOT APPLICABLE U.S. EPR design conforms to Regulatory Position 1.3.1.1.
1.3.1.3	For certain operating reactors for which the design cannot be practicably altered, if credit is taken for operation of an ECCS or containment heat removal pump in cavitation, prototypical pump tests should be performed along with post-test examination of the pump to demonstrate that pump performance will not be degraded and that the pump continues to meet all the performance criteria assumed in the safety analyses. The time period in the safety analyses during which the pump may be assumed to operate while cavitating should not be longer than the time for which the performance tests demonstrate that the pump meets performance criteria.	NOT APPLICABLE U.S. EPR design precludes ECCS pump operation in cavitation.
1.3.1.4	The decay and residual heat produced following accident initiation should be included in the determination of the water temperature. The uncertainty in the determination of the decay heat should be included in this calculation. The residual heat should be calculated	U.S. EPR design calculations for sump water temperature include decay heat (with margin) and all residual heat sources.

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	with margin	
1.3.1.5	The hot channel (i.e., fluid) correction factor specified in ANSI/HI 1.1-1.5-1994 should not be used in determining the margin between the available and required NPSH for ECCS and containment heat removal system pumps.	The assessment of available NPSH for the U.S. EPR ECCS pumps conservatively does not use the hot fluid correction factor specified in ANSI/HI 1.1-1.5-1994. (This factor permits a reduction in NSPH required).
1.3.1.6	The calculation of available NPSH should minimize the height of water above the pump suction (i.e., the level of water on the containment floor). The calculated height of water on the containment floor should not consider quantities of water that do not contribute to the sump pool (e.g., atmospheric steam, pooled water on floors and in refueling canals, spray droplets and other falling water, etc.). The amount of water in enclosed areas that cannot be readily returned to the sump should not be included in the calculated height of water on the containment floor.	The assessment of available NPSH for the U.S. EPR ECCS pumps is based on the minimum post LBLOCA water level in the IRWST.
1.3.1.7	The calculation of pipe and fitting resistance and the calculation of the nominal screen resistance without blockage by debris should be done in a recognized, defensible method or determined from applicable experimental data.	ECCS performance calculations properly treat pipe and fitting resistance and use a conservative value for ECCS screen resistance based on ECCS strainer testing results.
1.3.1.8	Sump screen flow resistance that is due to blockage by LOCA-generated debris or foreign material in the containment which is transported to the suction intake screens should be determined using Regulatory Position 1.3.4.	The assessment of available NPSH for the ECCS pumps is determined from screen pressure drop based on validation testing and the maximum expected debris loading.
1.3.1.9	Calculation of available NPSH should be performed as a function of time until it is clear that the available NPSH will not decrease further.	An assessment of available NPSH as a function of time was performed.
1.3.2	**Debris Sources and Generation**	

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1.3.2.1	Consistent with the requirements of 10 CFR 50.46, debris generation should be calculated for a number of postulated LOCAs of different sizes, locations, and other properties sufficient to provide assurance that the most severe postulated LOCAs are calculated. The level of severity corresponding to each postulated break should be based on the potential head loss incurred across the sump screen. Some PWRs may need recirculation from the sump for licensing basis events other than LOCAs. Therefore, licensees should evaluate the licensing basis and include potential break locations in the main steam and main feedwater lines as well in determining the most limiting conditions for sump operation.	The U.S. EPR design is based on the most penalizing break locations with respect to debris generation. The debris generation evaluation utilizes the guidance of NRC Regulatory Guidance 1.82 Rev.3 and information presented in Nuclear Energy Institute (NEI) 04-07. The U.S. EPR does not require recirculation from the IRWST for non-LOCA events. For the U.S. EPR, ECCS recirculation is not required for main steam or feedwater line breaks.
1.3.2.2	An acceptable method for estimating the amount of debris generated by a postulated LOCA is to use the zone of influence (ZOI). Examples of this approach are provided in NUREG/CR-6224 and Boiling Water Reactor Owners' Group (BWROG) Utility Resolution Guidance (NEDO-32686 and the staff's Safety Evaluation on the BWROG's response to NRC Bulletin 96-03). A representation of the ZOI for commonly used insulation materials is shown in Figure 3.	The ZOI method is used for determining the debris source for the U.S. EPR.
	• The size and shape of the ZOI should be supported by analysis or experiments for the break and potential debris. The size and shape of the ZOI should be consistent with the debris source (e.g., insulation, fire barrier materials, etc.) damage pressures, i.e., the ZOI should extend until the jet pressures decrease below the experimentally determined damage pressures appropriate for the debris source.	The U.S. EPR design uses the methodology presented in Nuclear Energy Institute (NEI) 04-07 for determining the ZOI.
	• The volume of debris contained within the ZOI should be used to estimate the amount of debris generated by a postulated break.	See below.
	• The size distribution of debris created in the ZOI should be	See below.

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	determined by analysis or experiments. • The shock wave generated during the postulated pipe break and the subsequent jet should be the basis for estimating the amount of debris generated and the size or size distribution of the debris generated within the ZOI. Certain types of material used in a small quantity inside the containment can, with adequate justification, be demonstrated to make a marginal contribution to the debris loading for the ECC sump. If debris generation and debris transport data have not been determined experimentally for such material, it may be grouped with another like material existing in large quantities. For example, a small quantity of fibrous filtering material may be grouped with a substantially large quantity of fibrous insulation debris, and the debris generation and transport data for the filter material need not be determined experimentally. However, such analyses are valid only if the small quantity of material treated in this manner does not have a significant effect when combined with other materials (e.g., a small quantity of calcium silicate combined with fibrous debris).	The U.S. EPR uses a conservative approach to determine the amount of debris generated within the ZOI. Specifically, all potential debris material within the ZOI is included in the debris source estimate. This debris then non-mechanistically assumed to be transported to the IRWST. The retaining basket head loss and ECC strainer head loss are determined by testing using this debris source term.
1.3.2.3	A sufficient number of breaks in each high-pressure system that relies on recirculation should be considered to reasonably bound variations in debris generation by the size, quantity, and type of debris. As a minimum, the following postulated break locations should be considered. • Breaks in the reactor coolant system (e.g., hot leg, cold leg, pressurizer surge line) and, depending on the plant licensing basis, main steam and main feedwater lines with the largest amount of potential debris within the postulated ZOI, • Large breaks with two or more different types of debris, including the breaks with the most variety of debris, within the expected ZOI,	The U.S EPR break selection process is based on the guidance of NRC Regulatory Guide 1.82 Rev 3, Section 1.3.2.3.

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	• Breaks in areas with the most direct path to the sump, • Medium and large breaks with the largest potential particulate debris to insulation ratio by weight, and • Breaks that generate an amount of fibrous debris that, after its transport to the sump screen, could form a uniform thin bed that could subsequently filter sufficient particulate debris to create a relatively high head loss referred to as the 'thin-bed effect.' The minimum thickness of fibrous debris needed to form a thin bed has typically been estimated at 1/8 inch thick based on the nominal insulation density (NUREG/CR-6224).	
1.3.2.4	All insulation (e.g., fibrous, calcium silicate, reflective metallic), painted surfaces, fire barrier materials, and fibrous, cloth, plastic, or particulate materials within the ZOI should be considered a debris source. Analytical models or experiments should be used to predict the size of the postulated debris. For breaks postulated in the vicinity of the pressure vessel, the potential for debris generation from the packing materials commonly used in the penetrations and the insulation installed on the pressure vessel should be considered. Particulate debris generated by pipe rupture jets stripping off paint or coatings and eroding concrete at the point of impact should also be considered.	The significant debris generating material within the ZOI has been considered in the developing debris source estimate for the U.S. EPR.
1.3.2.5	The cleanliness of the containment during plant operation should be considered when estimating the amount and type of debris available to block the ECC sump screens. The potential for such material (e.g., thermal insulation other than piping insulation, ropes, fire hoses, wire ties, tape, ventilation system filters, permanent tags or stickers on plant equipment, rust flakes from unpainted steel surfaces, corrosion products, dust and dirt, latent individual fibers)	Latent debris has been considered as part of the total debris source estimate. Control of material used and the overall cleanliness inside containment is a programmatic requirement. Refer to U.S. EPR FSAR COL Information Item 6.3-1 (Table 1.8-2).

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	to impact head loss across the ECC sump screens should also be considered.	
1.3.2.6	In addition to debris generated by jet forces from the pipe rupture, debris created by the resulting containment environment (thermal and chemical) should be considered in the analyses. Examples of this type of debris would be disbondment of coatings in the form of chips and particulates or formation of chemical debris (precipitants) caused by chemical reactions in the pool.	Debris created by the resulting containment environment (thermal and chemical) is considered in the U.S. EPR analyses. Included in these debris types are disbondment of coatings and formation of chemical debris (precipitants).
1.3.2.7	Debris generation that is due to continued degradation of insulation and other debris when subjected to turbulence caused by cascading water flows from upper regions of the containments or near the break overflow region should be considered in the analyses.	All insulation and debris generating material within the ZOI has been conservatively assumed to reach the retaining baskets. Additionally, quantities for latent debris, paint chips, and micro-porous insulating material have been included in the debris source term and are representative of such additional debris contribution from outside of the ZOI.
1.3.3	**Debris Transport**	
1.3.3.1	The calculation of debris quantities transported from debris sources to the sump screen should consider all modes of debris transport, including airborne debris transport, containment spray washdown debris transport, and containment sump pool debris transport. Consideration of the containment pool debris transport should include (1) debris transport during the fill-up phase, as well as during the recirculation phase, (2) the turbulence in the pool caused by the flow of water, water entering the pool from break overflow, and containment spray drainage, and (3) the buoyancy of the debris. Transport analyses of debris should consider: (1) debris that	The assessment of ECCS sump strainer blockage is conservatively bounded by the assumption that all available insulation and debris within the ZOI is transported to the IRWST. Also included in the debris source estimate is an amount of debris representing the contribution from outside the ZOI.

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	would float along the pool surface, (2) debris that would remain suspended due to pool turbulence (e.g., individual fibers and fine particulates), and (3) debris that readily settles to the pool floor.	
1.3.3.2	The debris transport analyses should consider each type of insulation (e.g., fibrous, calcium silicate, reflective metallic) and debris size (e.g., particulates, fibrous fine, large pieces of fibrous insulation). The analyses should also consider the potential for further decomposition of the debris as it is transported to the sump screen.	The assessment of ECCS sump strainer clogging conservatively assumes all debris is non-mechanistically transported to the IRWST.
1.3.3.3	Bulk flow velocity from recirculation operations, LOCA-related hydrodynamic phenomena, and other hydrodynamic forces (e.g., local turbulence effects or pool mixing) should be considered for both debris transport and ECC sump screen velocity computations.	LOCA recirculation flow characteristics for the U.S. EPR™ are considered for assessing both debris transport and ECC sump screen velocity.
1.3.3.4	An acceptable analytical approach to predict debris transport within the sump pool is to use computational fluid dynamics (CFD) simulations in combination with the experimental debris transport data. Examples of this approach are provided in NUREG/CR-6772 and NUREG/CR-6773. Alternative methods for debris transport analyses are also acceptable, provided they are supported by adequate validation of analytical techniques using experimental data to ensure that the debris transport estimates are conservative with respect to the quantities and types of debris transported to the sump screen.	NOT APPLICABLE: Conservative assumptions regarding debris transport have been used; hence, use of CFD is unnecessary.
1.3.3.5	Curbs can be credited for removing heavier debris that has been shown analytically or experimentally to travel by sliding along the containment floor and that cannot be lifted off the floor within the calculated water velocity range.	U.S. EPR design incorporates a weir (curb) that prevents heavier debris from entering the retaining basket. This has been validated by testing.
1.3.3.6	If transported to the sump pool, all debris (e.g., fine fibrous, particulates) that would remain suspended due to pool turbulence should be considered to reach the sump screen.	Debris transported to the IRWST will first encounter the retaining baskets which will remove a majority of the debris. Debris

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		which passes through the retaining baskets will not encounter any turbulence due to IRWST size. This has been demonstrated by testing. Hence, suspended particulates were not directly considered downstream of the retaining basket. Instead, the ECC strainer was conservatively sized based on 2 times the maximum design head loss and the quantity of debris reaching the ECC strainer. As part of the U.S. EPR design program, testing with different ratios of particulate to fiber volume will validate the above assumption (i.e., assess thin-bed layer effects).
1.3.3.7	The time to switch over to sump recirculation and the operation of containment spray should be considered in the evaluation of debris transport to the sump screen.	NOT APPLICABLE: The U.S. EPR design features include an IRWST. As such, the ECCS pumps continuously operate in a recirculation mode post-LOCA.
1.3.3.8	In lieu of performing airborne and containment spray washdown debris transport analyses, it could be assumed that all debris will be transported to the sump pool. In lieu of performing sump pool debris transport analyses (Regulatory Position 1.3.3.4), it could be	Conservative assumptions regarding debris transport and quantity of debris have been used in the evaluation of U.S. EPR ECCS sump performance.

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	assumed that all debris entering the sump pool or originating in the sump will be considered transported to the sump screen when estimating screen debris bed head loss. If it is credible in a plant that all drains leading to the containment sump could become completely blocked, or an inventory holdup in containment could happen together with debris loading on the sump screen, these situations could pose a worse impact on the recirculation sump performance than the assumed situations mentioned above. In this case, these situations should also be assessed.	Furthermore, given the multiple pathways for water to drain to the IRWST, complete blockage of all pathways to the IRWST is considered to be not credible.
1.3.3.9	The effects of floating or buoyant debris on the integrity of the sump screen and on subsequent head loss should be considered. For screens that are not fully submerged or are only shallowly submerged, floating debris could contribute to the debris bed head loss. The head loss due to floating or buoyant debris could be minimized by a design feature to keep buoyant debris from reaching the sump screen	The U.S. EPR design is not affected by floating debris because even with the IRWST at minimum water level, the ECC sumps are significantly submerged.
1.3.4	**Debris Accumulation and Head Loss**	
1.3.4.1	ECC sump screen blockage should be evaluated based on the amount of debris estimated using the assumptions and criteria described in Regulatory Position 1.3.2 and on the debris transported to the ECC sump per Regulatory Position 1.3.3. This volume of debris should be used to estimate the rate of accumulation of debris on the ECC sump screen.	The performance of the U.S. EPR ECC sump strainers is based on conservative assumptions relative to the quantity of debris, ECC flow, and temperature conditions.
1.3.4.2	Consideration of ECC sump screen submergence (full or partial) at the time of switchover to ECCS should be given in calculating the available (wetted) screen area. For plants in which containment heat removal pumps take suction from the ECC sump before switchover to the ECCS, the available NPSH for these pumps should consider the submergence of the sump screens at the time these pumps initiate suction from the ECC sump. Unless otherwise	The performance of the U.S. EPR ECC sump strainers is based on conservative assumptions relative to the quantity of debris, ECC flow, and temperature conditions. The strainer design provides sufficient screen area for acceptable screen head loss under debris laden

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	shown analytically or experimentally, debris should be assumed to be uniformly distributed over the available sump screen surface. Debris mass should be calculated based on the amount of debris estimated to reach the ECC sump screen. (See Revision 1 of NUREG-0897, NUREG/CR-3616, and NUREG/CR-6224.)	conditions. The screen head loss is validated by testing. The U.S. EPR design is such that the ECC sumps remain continuously submerged.
1.3.4.3	For fully submerged sump screens, the NPSH available to the ECC pumps should be determined using the conditions specified in the plant's licensing basis.	The performance of the U.S. EPR ECCS sump strainers is based on conservative assumptions relative to the quantity of debris, ECC flow, and temperature conditions.
1.3.4.4	For partially submerged sumps, NPSH margin may not be the only failure criterion, as discussed in Appendix A. For partially submerged sumps, credit should only be given to the portion of the sump screen that is expected to be submerged, as a function of time. Pump failure should be assumed to occur when the head loss across the sump screen (including only the clean screen head loss and the debris bed head loss) is greater than one-half of the submerged screen height or NPSH margin.	NOT APPLICABLE: The U.S. EPR design is such that the ECC sumps remain continuously submerged.

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1.3.4.5	Estimates of head loss caused by debris blockage should be developed from empirical data based on the sump screen design (e.g., surface area and geometry), postulated combinations of debris (i.e., amount, size distribution, type), and approach velocity. Because debris beds that form on sump screens can trap debris that would pass through an unobstructed sump screen opening, any head loss correlation should conservatively account for filtration of particulates by the debris bed, including particulates that would pass through an unobstructed sump screen.	The performance of the U.S. EPR ECC strainers is based upon strainer validation testing. While the testing included a mix of particulates, micro-porous insulating material, paint chips, and mineral wool, no relevant thin-bed effects were observed. The U.S. EPR design process will evaluate additional empirical data to further assess the presence or lack of thin bed effects.
1.3.4.6	Consistent with the requirements of 10 CFR 50.46, head loss should be calculated for the debris beds formed of different combinations of fibers and particulate mixtures (e.g., minimum uniform thin bed of fibers supporting a layer of particulate debris) based on assumptions and criteria described in Regulatory Positions 1.3.2 and 1.3.3.	See response to 1.3.4.5, above.
2.	**BOILING WATER REACTORS** Regulatory Guide 1.82 (top of page 1.82-4) states that for <u>advanced designs</u>, the regulatory positions for <u>both</u> PWRs and BWRs should be considered (as appropriate to the plant's design). The example given, a PWR with an in-containment refueling water storage tank (IRWST) that is similar to the suppression pool in a BWR, is directly relevant to the U.S. EPR design.	The RG 1.82 guidance for BWRs was reviewed for applicability to the U.S. EPR. Most of the BWR guidance items have a similar, if not identical, counterpart item in the PWR guidance. The review did identify five items that are unique to BWRs. These items are assessed for U.S. EPR applicability below.

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2.3.1	**Debris Sources and Generation**	
2.3.1.7	The amount of particulates estimated to be in the pool prior to a LOCA should be considered to be the maximum amount of corrosion products (i.e., sludge) expected to be generated since the last time the pool was cleaned. The size distribution and amount of particulates should be based on plant samples.	The amount of particulates contained in the IRWST prior to a LOCA is insignificant. Materials of construction for the IRWST are compatible with contained fluid chemistry; hence, no corrosion products are expected. In addition, the FPPS provides for IRWST cleaning and the tank internals and liner are constructed of austenitic stainless steel. The U.S. EPR design process concludes resident debris material in the IRWST prior to the LBLOCA to be insignificant.
2.3.2	**Debris Transport**	
2.3.2.2	It should be assumed that LOCA-induced phenomena (i.e., pool swell, chugging, condensation oscillations) will suspend all the debris assumed to be in the suppression pool at the onset of the LOCA.	NOT APPLICABLE: Unlike a BWR suppression pool, the lost coolant does not enter the IRWST through submergence. Hence, phenomena contributing to significant mixing in the IRWST are absent.
2.3.2.3	The concentration of debris in the suppression pool should be calculated based on the amount of debris estimated to reach the suppression pool from the drywell and the amount of debris and foreign materials estimated to be in the suppression pool prior to a postulated break.	Debris transported to the IRWST will first encounter the retaining baskets which will remove a majority of the debris. The amount of particulates contained in the IRWST prior to a LOCA is expected to be insignificant as explained in 2.3.1.7 above.

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		The U.S. EPR design process concludes resident debris material in the IRWST prior to the LBLOCA to be insignificant.
2.3.2.4	Credit should not be taken for debris settling until LOCA-induced turbulence in the suppression pool has ceased. The debris settling rate for the postulated debris should be validated analytically or experimentally.	The U.S. EPR design does not take credit for debris settling. Refer to 1.3.3.6, above.
2.3.3	**Strainer Blockage and Head Loss**	
2.3.3.2	The flow rate through the strainer should be used to estimate the rate of accumulation of debris on the strainer surface.	The combined flow from LHSI and MHSI is used to determine the ECC strainer differential pressure. Because a conservative calculation approach is used, the estimate of rate of debris accumulation on the strainer surface was not determined.