Screening Analysis Report

Introduction

The proposed Generic Issue (GI) relates to the effects a downstream dam failure would have on the availability of cooling and service water (i.e., ultimate heat sink (UHS) at operating nuclear power plants (NPPs)). Based on analyses related to the frequency of dam failures,[1] the staff questioned whether the state of knowledge may have changed sufficiently to warrant evaluation by the GI program.

Scope of the Proposed Generic Issue

The staff used NUREG-0965, "NRC Inventory of Dams," to determine the applicability of the proposed GI to two or more NPPs. Within NUREG-0965, the NRC identified 27 NPP sites containing 51 dams that form 33 impoundments. Of those, 5 NPP sites did not complete construction or have permanently shutdown. Some impoundments are formed by more than one dam. NUREG-0965 identifies dams for which the NRC might be considered the "responsible" authority in terms of the Federal guidelines. Twenty onsite dams (14 impoundments) meet the Federal guidelines to be considered under NRC responsibility. It is noted in NUREG-0965 that state agencies, rather than the NRC, license several of the onsite non-seismic Category I dams. NUREG-0965 also lists operating NPPs with offsite dams impounding normal and/or emergency cooling water. The NRC does not regulate the offsite dams.

The impoundment for the emergency cooling water is typically a seismic Category I structure, formed by a submerged or partially submerged dam within the larger principal reservoir. The staff has identified 13 NPP sites with 21 units that rely on onsite and/or offsite downstream dams to impound water for emergency cooling. Table 1 lists these sites.

During an emergency, a NPP typically draws water first from an impoundment reservoir providing the normal water supply to the plant. However, for some sites, the UHS does not credit the impoundment reservoir. For example, emergency cooling water at Browns Ferry is first drawn from the water impounded by Wheeler Dam, but a channel in the Tennessee River itself is credited as the UHS. Section 4.2 of the Browns Ferry final safety analysis report (FSAR) states:

> Failure of Wheeler Dam would require Browns Ferry plant to be shut down. The postulation of this event required an investigation into the effectiveness of the remaining reservoir to provide adequate cooling water for the plant. If Wheeler Dam were to fail, a pool of water approximately 1000 feet wide and seven miles long … would be available at the Browns Ferry plant site.

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[1] F. Ferrante, S. Sancaktar, J. Mitman, J. Wood. "An Assessment of Large Dam Failure Frequencies based on US Historical Data," *Proceedings of ANS PSA 2011 International Topical Meeting on Probabilistic Safety Assessment and Analysis,* Wilmington, NC: American Nuclear Society, 2011.

Table 1: NPP Sites Using Impoundment Reservoirs for Emergency Cooling

NPP Site	Reactors	Dams	Dam Description (regulator)
Catawba	2	1	onsite submerged dam (NRC)
Clinton	1	1	onsite submerged dam (NRC)
Comanche Peak	2	1	onsite submerged dam (NRC)
Farley	2	1	storage pond dam (NRC)
Shearon Harris	1	1	auxiliary dam (NRC)
McGuire	2	1	standby nuclear service water dam (NRC)
North Anna	2	2	service water reservoir dikes (NRC)
Oconee [a]	3	1	onsite submerged dam (NRC)
Peach Bottom [b]	2	1	Conowingo Dam (FERC[c])
H.B. Robinson	1	1	Lake Robinson Dam (FERC)
V.C. Summer	1	3	onsite submerged dams (NRC)
Vermont Yankee	1	1	Vernon Dam (FERC)
Wolf Creek	1	1	onsite submerged dam (NRC)

[a] UHS credit is given to the water trapped in the condenser circulating water piping (see FSAR Section 9.2.3).
[b] UHS credit is given to the cooling tower basin (see Peach Bottom's updated final safety analysis report, Section 10.24, Appendix J, Section J.2.3, and Technical Specification Bases 3.7.3).
[c] Federal Energy Regulatory Commission

The above statement indicates that a downstream (Wheeler) dam failure was considered in the original design at Browns Ferry. NUREG-0965 notes that the emergency intake for Browns Ferry is the Tennessee River Channel. However, river channels may change gradually over time because of effects from natural phenomena, such as silting. Also, channels may change dramatically from extreme flow changes caused by flooding that would occur from a dam failure. Therefore, there exists a possibility for extreme external events to affect the UHS for NPPs.

Nuclear facilities other than NPPs were considered for possible inclusion in the scope of this proposed GI. A review was done by the Office of Nuclear Material Safety and Safeguards (NMSS) to determine if any NMSS-regulated facilities require safety-related cooling from a dammed reservoir. NRC staff in the Office of Nuclear Reactor Regulation (NRR) carried out a similar review to determine whether any research or test reactors rely on a dammed reservoir for their UHS. In both instances, no nuclear facilities were identified as being adversely affected by a dam failure.

Decommissioned NPPs may rely on impoundment reservoirs as the UHS for removing decay heat from their spent fuel pools (SFPs). The low heat load present in decommissioned NPP SFPs would lead to an extensive time in order to uncover the fuel. For example, for fuel that has been decaying for 2 years, the time for the pool to heat up and boil down to 3 feet above the top of the fuel is 11 days for a pressurized-water reactor and 14 days for a boiling-water reactor.[2] This amount of time is sufficient to allow solutions to replace the heat sink to be developed and implemented. Therefore, the Generic Issues Review Panel (the Panel) decided that decommissioned NPPs are not in the scope of the proposed GI.

The NRC categorizes NPPs as "operating reactors" or "new reactors." Over the years, the NRC has updated the review guidance and standards used in the licensing of NPPs. The purpose of the proposed generic issue is to evaluate downstream dams in light of NRC's current guidance

[2] NUREG-1738, "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants," ADAMS Accession No. ML010430066.

and standards to determine whether any safety issues arise. The NRC is already applying the current guidance and standards in the licensing of new reactors. As a result, the Panel determined that the scope of the proposed generic issue does not apply to new reactors.

Based upon a review of nuclear facilities, the panel concluded that the scope of the proposed GI should be limited to operating NPPs.

Description of the Potential Effects on Plants

The cooling water for normal and/or emergency operations at NPPs can be provided by reservoirs formed by dams blocking a river or stream, thereby creating an onsite lake or pond for the UHS. In such cases, failure of the dam could affect the availability of cooling water for safety functions such as removal of heat from containment cooling systems and reactor decay heat removal cooling systems. The loss of UHS because of failure of one or more dams differs from other postulated events that can cause the temporary loss of UHS (e.g., clogging of intake screens, failure of individual components, etc.). The primary difference is the capability of site personnel to recover from the event. It may be possible to remove obstructions blocking an intake screen, but it is not possible to replace a failed dam in a relatively short period of time.

Depending on specific plant design characteristics, the available sources of cooling water, the configuration of plant intake systems, and external conditions, a loss of UHS that is not readily recoverable could result in an inability to cool safety-related heat loads within the plant under certain scenarios. In light of recently published data on dam failure frequency estimates [3] and seismic hazard estimates [4], the NRC staff questioned whether the risk from loss of the UHS should be re-evaluated based on the improved understanding of the hazards affecting dam safety.

Regulatory Background

General Design Criterion (GDC) 44 of Appendix A to Part 50 of NRC Regulations, under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, ("Cooling Water") states:

> A system to transfer heat from structures, systems, and components important to safety, to an ultimate heat sink shall be provided. The system safety function shall be to transfer the combined heat load of these structures, systems, and components under normal operating and accident conditions.
>
> Suitable redundancy in components and features, and suitable interconnections, leak detection, and isolation capabilities shall be provided to assure that for onsite electric power system operation (assuming offsite power is not available) and for offsite electric power system operation (assuming onsite power is not available) the system safety function can be accomplished, assuming a single failure.

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3 "Uncertainty Analysis for Large Dam Failure Frequencies Based on Historical Data," ADAMS Accession No. ML13198A170.

4 "Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States (CEUS) on Existing Plants," Generic Issue 199, ADAMS Accession No. ML100270639.

GDC 2 of Appendix A to 10 CFR Part 50 ("Design Bases for Protection against Natural Phenomena") states:

> Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena and (3) the importance of the safety functions to be performed.

Some plants were licensed before the adoption of the GDC. These plants were separately evaluated under the NRC's Systematic Evaluation Program. In SECY-92-233,[5] the Commission approved the staff's proposal to not apply GDC criteria to plants with construction permits prior to May 21, 1971. Those plants receiving construction permits prior to 1971 would be evaluated on a plant-specific basis to determine whether they meet the intent of the GDCs.

Standard Review Plan [6] (SRP) Section 9.2.5 ("Ultimate Heat Sink") provides regulatory guidance for the NRC staff to use when reviewing water sources that make up the UHS to ensure that they are capable of performing their safety functions. The SRP also discusses site characteristics that could affect the design and siting of the plant. Section 9.2.5 interfaces with Sections 2.4.1 - 2.4.14, which address the review of UHS water levels, water control structures (including dams), meteorological and natural phenomena criteria, and transient analysis of the cooling water inventory.

Dams are susceptible to a variety of failure mechanisms, several of which could be initiated by large natural events, such as earthquakes and floods. SRP Section 9.2.5 interfaces with Sections 3.3.1, 3.3.2, 3.4.2, 3.5.3, 3.7.1 through 3.7.4, 3.8.4, and 3.8.5, addressing the review of the design analysis, procedures, and criteria establishing the capability of seismic Category I structures to withstand the effects of natural phenomena like the safe-shutdown earthquake (SSE), the probable maximum flood, and tornado missiles. In Chapter 2 of the SRP, the hydrological design basis is developed to ensure that any potential hazard to the safety-related facilities due to the failure of onsite, upstream, and downstream water control structures are considered in plant design. Although, there is regulatory guidance related to seismic and hydrologic dam failure modes, guidance for other common dam failure modes (e.g., internal erosion) is relatively limited. Also, there is no current NRC requirement that the licensee update its original deterministic guidance as knowledge regarding hydrologic dam failures evolves. Additional guidance is provided in SRP Section 2.4.8, ("Cooling Water Canals and Reservoirs"),

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5 "Resolution of Deviations Identified during the Systematic Evaluation Program" (SECY-93-223), ADAMS Accession No. ML12256B290.

6 Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition (NUREG-0800), formerly issued as NUREG-75/087," http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0800/

Section 2.4.11 ("Low Water Considerations"), and Section 6.2.2 ("Containment Heat Removal Systems").

NRC interim staff guidance (ISG) issued by the Japan Lessons-Learned Project Directorate (JLD) (now Japan Lesson-Learned Division), JLD-ISG-2013-01 [7] presents an overview of dams, types and causative mechanisms for dam failure, and the basic approach to estimating flooding hazards due to dam failure. It is expected that licensees will use this ISG when evaluating seismic and flooding hazards to upstream and downstream dams during their implementation of Near-Term Task Force (NTTF) Recommendation 2.1. Licensees are expected to use this ISG when evaluating random (sunny day) failures of upstream dams under NTTF Recommendation 2.1. This ISG could also be used for the evaluation of random (sunny day) failures of downstream dams during the evaluation of this proposed GI.

Description of Technical Issues

The UHS at NPPs are designed to provide a heat sink for decay heat removal systems from the reactor core, containment, and SFPs. If not removed, the decay heat generated by the reactor core is capable of causing core damage by raising fuel temperatures beyond their peak design temperatures and challenging the integrity of the reactor coolant pressure boundary. Containment designs also rely on the rejection of heat to an UHS to maintain containment temperatures below their design limits. The inability to remove decay heat can eventually result in the loss of containment integrity.

Dams may play a significant role in maintaining the integrity of a UHS. Dams are susceptible to failure from a variety of mechanisms, such as overtopping due to severe flooding, earthquakes, internal erosion, degradation, mechanical malfunctions, operational deficiencies, or a combination of multiple mechanisms. Due to revision of analyses and the availability of a higher quality and larger quantity of data, estimates of the frequency and magnitude of these initiators have changed for some sites. A brief summary of dam failure mechanisms is provided below:

Seismic Initiators

New seismological data and models have resulted in increased estimates of the seismic hazard at some NPP sites. The risk associated with the increase in risk from a seismic hazard is being evaluated for existing NPPs in the Central and Eastern United States under GI-199.[8]

Flooding

Overtopping due to severe flooding or operational deficiencies is a potential failure mechanism for large water impounding structures and accounts for approximately one-third of all dam failure

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7 "Interim Staff Guidance for Assessment of Flooding Hazards Due to Dam Failure," ADAMS Accession No. ML13151A153.

8 "Safety/Risk Assessment Results for Generic Issue 199, 'Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants,'" ADAMS Accession No. ML100270582.

events.[9] Past studies by several licensees indicate that estimates of flooding at sites due to dam failures are larger than previously calculated, suggesting that the existing design-basis flood estimates, which affect both the site and the dam's impounding cooling water, may not be bounding.

Random (Sunny Day) Failures

Internal erosion and foundation defects account for approximately half of all dam failure events in the United States.[10] These failures are commonly referred to as "sunny day" failures in the sense that they pertain to latent construction/design flaws which can cause a dam to fail, absent an initiating event like a flood or earthquake.

Empirical Estimates of Dam Failure Frequency

Significant NRC discussions have taken place on the issue of estimating a credible dam failure rate. A recent assessment [11] by NRC staff used available databases to compute an empirical estimate of dam failure frequency of 2.9E-4/year. This is on the same order of magnitude as the 1E-4/year failure frequency [12] that the Bureau of Reclamation uses as an approximate estimate for large dams that have no apparent tendency toward more adverse or more favorable conditions. These recent analyses indicate that the frequency of dam failure events may be larger than reported in past NRC and industry reports aimed at screening for the consideration of natural phenomena in vulnerability studies, (e.g., "Evaluation of External Hazards to Nuclear Power Plants in the United States").[13] In some cases, the estimates of dam failure frequency used in the vulnerability studies were carried forward to subsequent risk analyses. Data available in these databases, performance insights, and approximate generic dam failure rate estimates are useful in identifying failure mechanisms. However, they may not provide sufficient basis for developing site-specific estimates or to assess the contribution of external flooding or loss of ultimate heat sink to the overall plant risk. By including a large population of dams with a wide variety of features, the resulting failure frequency may or may not be appropriate for evaluating one specific dam or NPP site.

<u>Correlation with NTTF Activities</u>

Following the accident at the Fukushima Dai-ichi NPP on March 11, 2011, the NRC established the NTTF in response to Commission direction. The NTTF was tasked with conducting a systematic and methodical review of NRC processes and regulations to address effects on

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9 ASDSO. "Association of State Dam Safety Officials: Dam Failures and Incidents," available at http://www.damsafety.org/news/?p=412f29c8-3fd8-4529-b5c9-8d47364c1f3e#FailureCauses (accessed January 5, 2011), 2011.

10 ASDSO. "Association of State Dam Safety Officials: Dam Failures and Incidents," available at http://www.damsafety.org/news/?p=412f29c8-3fd8-4529-b5c9-8d47364c1f3e#FailureCauses (accessed January 5, 2011), 2011.

11 F. Ferrante, S. Sancaktar, J. Mitman, J. Wood. "An Assessment of Large Dam Failure Frequencies based on US Historical Data," *Proceedings of ANS PSA 2011 International Topical Meeting on Probabilistic Safety Assessment and Analysis,* Wilmington, NC: American Nuclear Society, 2011.

12 U.S. Department of the Interior, Bureau of Reclamation, in cooperation with U.S. Army Corps of Engineers, *Dam Safety Risk Analysis Best Practices Training Manual*, Version 2.2, April 2011.

13 U.S. Nuclear Regulatory Commission. "Evaluation of External Hazards to Nuclear Power Plants in the United States," NUREG/CR-5042, Page 5-8, December 1987, ADAMS Accession No. ML111950285.

NPPs in the United States from similar external events. The NRC staff requested all licensees under 10 CFR 50.54(f) to re-evaluate the seismic and flooding hazards at their sites using updated seismic and flooding hazard information and present-day regulatory guidance and methodologies. Therefore, the NRC is addressing seismic and flooding hazards to NPPs under current regulatory processes.

During the January and February 2013 meetings, the panel met with NRC staff to discuss actions being taken as a result of the NTTF Report. The panel concluded that NRC activities under NTTF Recommendations 2.1, 2.3, 4.1, and 4.2 were addressing seismic and flooding hazards to downstream UHS impoundment dams. The panel also concluded that NRC activities were not specifically addressing random "sunny day" failures of all downstream UHS impoundment dams.

The NRC also has a program in place to require licensees to implement mitigation strategies for beyond-design-basis external events. For NPPs with downstream dams that are not seismically robust, the NRC's mitigation strategies program is requiring licenses to address sources and access to water supplies in instances where the primary source of water (e.g. downstream dam) is not available. As such, the need for an alternative source of water for the UHS is being addressed for operating NPPs with non-seismic downstream dams through NRC's mitigation strategies program. This alternative source of water could also be relied upon in the event of a random failure of the downstream dam. That is to say, the need for the alternative source of water is not dependent upon whether the downstream dam failed as a result of a seismic event or whether it failed due to a random event. As a result, the Panel concluded that measures to mitigate a random failure of non-seismic downstream dams impacting the UHS were being adequately addressed through an ongoing NRC program. However, random failure of seismically categorized downstream dams is not covered because, if a downstream dam or downstream impoundment reservoir was categorized as seismic, the NRC under the mitigation strategies program considered the structure robust and therefore, an assessment of alternative sources of water was not required.

To address random failure of seismically categorized downstream dams, the NRC staff conducted a screening risk analysis and presented the results to the Panel. The results indicated that the change in core damage frequency (CDF) for all but two plants (Farley and North Anna) was very small and within the region "Exclude from further consideration" in Figure A2 of TEC-002. The results for Farley and North Anna were just above the threshold to justify continuance in the GI program, which narrowed the scope of the proposed GI to these 2 plants.

Because the calculated risk for these plants was just above the threshold, the NRC staff performed a more detailed sensitivity risk evaluation of these 2 plants. The staff also analyzed 2 additional plants (Catawba and Robinson) that had unique system configurations. The results of the sensitivity risk evaluation were then compared against the results from the screening risk analysis.

Summary of Results from Risk Evaluations

NPP	CDF from Downstream Dam Failure (Screening Risk Analysis)	CDF from Downstream Dam Failure (Sensitivity Risk Evaluation)
Farley	6.4×10^{-6}	6.5×10^{-8}
North Anna	4.0×10^{-6}	4.1×10^{-8}
Catawba	4.8×10^{-7}	4.4×10^{-9}
Robinson	1.1×10^{-7}	3.1×10^{-5}

The evaluations of Farley, North Anna, and Catawba revealed that these sites have two separate UHS reservoirs. One of the two reservoirs is a safety-related, seismic service water reservoir; the other reservoir is a lake or river associated with heat removal from normal plant operations. Either reservoir can be utilized by the plant as the UHS. Having redundant UHS lowered the CDF from downstream dam failure for Farley, North Anna, and Catawba. Based upon the evaluations, the panel concluded that the risk did not meet the threshold for continuation as defined in Figure A2 of TEC-002.

With regards to Robinson, the sensitivity risk analysis indicated that the risk met the threshold for issues that should be considered for further evaluation in the Generic Issues program. The Robinson results were unique and driven by uncertainty as to whether two separate UHS water sources exist at the site to mitigate the event. Given the uncertainty, no credit was given for a second UHS water source in the sensitivity risk analysis. Robinson was identified as the only NPP with just once source of water for the UHS in NUREG-0965, “NRC Inventory of Dams.” The staff confirmed this through a review of the NRC’s Interim Staff Evaluation (ISE) prepared in response to the Mitigating Strategies Order that the NRC issued in response to the Fukushima Dai-ichi accident. The Panel notes that the Robinson Updated Final Safety Analysis Report (UFSAR) states that there are on-site deep water wells that can be connected to the heat exchangers for the emergency diesel generators and backfed to the service water system. There is also some information discussing the potential use of alternative sources of water to the service water system. NRC’s risk analysis tools mention these water sources; however, sufficient information on these sources was not available. Therefore, they were not credited in the sensitivity risk analysis as a redundant source of emergency cooling water. Also, these water sources were not credited in the Robinson mitigating strategies because they are not assumed to be available following a beyond-design-basis external event. With no credit taken for these alternative water sources, the potential Generic Issue at the Robinson site meets the threshold in TEC-002 for further consideration. If sufficient credit is given for the alternative water sources, the calculated risk would be lower and the potential Generic Issue at the Robinson site would not meet the threshold for further consideration.

As a final check, the staff reassessed all plants using information in NUREG-0965, the NRC’s ISE reports, and the UFSARs to confirm that two separate (i.e., redundant) UHS water sources existed. Redundancy significantly mitigates the impact of a random failure of a downstream dam. The reassessment confirmed that all the plants with downstream dams have two UHS water sources, except for the Robinson plant. As Robinson is the only plant potentially adversely affected by a random failure of a downstream dam, the proposed generic issue does not meet criterion 2, “The issue applies to two or more facilities and/or licensees/certificate holders, or holders of other regulatory approvals.”

Regarding Robinson, the purpose of the Panel was to determine whether an issue should proceed to the next step in the Generic Issues Program; it is not to evaluate the unique aspects of one particular site. As a result, the Panel did not conduct any further evaluation of the Robinson site to determine whether credit could be taken for the deep water wells as an alternate supply of water for the UHS.

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F. Ferrante, S. Sancaktar, J. Mitman, J. Wood. "An Assessment of Large Dam Failure Frequencies based on US Historical Data," *Proceedings of ANS PSA 2011 International Topical Meeting on Probabilistic Safety Assessment and Analysis,* Wilmington, NC: American Nuclear Society, 2011.

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