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UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
OFFICE OF NUCLEAR REACTOR REGULATION  
WASHINGTON, DC 20555-0001

NRC INFORMATION NOTICE 2009-xx: UNDERESTIMATE OF DAM FAILURE  
FREQUENCY USED IN PROBABILISTIC RISK  
ASSESSMENTS

**ADDRESSEES**

All holders of operating licenses for nuclear power reactors, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

**PURPOSE**

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to alert addressees of a ~~non-conservative value for underestimation of a~~ dam failure frequency that originated in 1980s reference documents and ~~was may have been~~ commonly adopted by licensees in their probabilistic risk assessment (PRA) for external events. Using a ~~non-conservative partial~~ dam failure frequency may result in underestimating the risks to the plant associated with external flooding or loss of heat sink from the failure of upstream and downstream dams or levees. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to correct any error resulting from the reference documents. However, suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

**DESCRIPTION OF CIRCUMSTANCES**

The NRC staff ~~recently has~~ identified a non-conservative value for dam failure frequency contained in the Nuclear Safety Analysis Center (NSAC) report NSAC/60, "Oconee PRA: A Probabilistic Risk Assessment of Oconee Unit 3." Published in 1984, NSAC/60 was prepared by NSAC in conjunction with Duke Power Company and provided a calculated value for the dam failure frequency of the Jocassee dam, a value commonly referenced by other licensees in their flooding analyses. The NSAC/60 PRA model determined the failure frequency for the Jocassee dam by compiling failure data for similar types of dams, but inappropriately excluded several modes of failure. The NSAC/60 results state the mean failure frequency for the Jocassee dam to be  $2.5 \times 10^{-5}$ /year. The NRC has determined the failure frequency could be an order of magnitude higher.

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**DISCUSSION**

A recent NRC is reviewing of a significance determination process (SDP) finding identified an incorrect analysis that resulted in a underestimated non-conservative value for the failure frequency of the Jocassee dam contained in the report NSAC/60, "Oconee PRA: A Probabilistic Risk Assessment of Oconee Unit 3." The NSAC/60 dam failure frequency determination was referenced in NUREG/CR-5042, "Evaluation of External Hazards to Nuclear Power Plant in the United States," initially published in 1987. The recommendations of NUREG/CR-5042 may have influenced other licensees to use the NSAC/60 results as a generic dam failure rate. There is a two-fold concern with using the NSAC/60 results as a generic dam failure rate. First, the NSAC/60 calculated failure rate is a site-specific calculation for the Jocassee Dam. This dam-specific calculated failure rate may not be applicable to other dams and thus can not be indiscriminately applied to other dams generically. Second, the analysis used to calculate the Jocassee specific failure rate in NSAC/60 inappropriately excluded failure data, yielding a non-conservative value. The following paragraphs discuss this concern in detail.

During a recent review, the NRC staff noted that many exclusions of data from the PRA model used in NSAC/60 in estimating a frequency of failures of the Jocassee dam were not appropriate. Specifically, the choice of exclusions by NSAC/60 included the majority of failure modes that had historically resulted in dam failure for the category of dams to which Jocassee dam belongs. The NSAC/60 failure mode exclusions were earthquakes, overtopping, failures from piping at a conduit passing through a dam, and structural failures of spillways during floods. The NSAC/60 exclusions of these failure modes were based on deterministic considerations related to the Jocassee dam rather than probabilistic considerations, and, on that basis, NRC does not consider such exclusions appropriate. Exclusions should not be applied in PRA analysis unless the failure cannot physically happen. Therefore, in the Jocassee dam case, probabilities-frequencies can and should be assigned for each of these failure types. In addition, the resulting Jocassee dam failure frequency in the NSAC/60 model is based upon the completeness and accuracy of the data used and the criteria for excluding certain failures. NSAC/60 discusses failures that were included but, unfortunately, does not address failures which were excluded. Further, the NSAC/60 report does not clearly state what population of dams or dam-types were used to develop the dam-years associated with the failure frequency.

The NRC staff has recalculated the failure frequency that would be applicable to rockfill dams similar to Jocassee dam using failure data from the National Performance of Dams Program at <http://npdp.stanford.edu> and the dam descriptions and using population data from the National Inventory of Dams at <http://crunch.tec.army.mil/nid/webpages/nid.cfm>. Because rockfill dams are earthen dams with a rockfill cover, the NRC included both rockfill and earthen dam failures. NRC's assessment has shown that these sources are adequate to support obtaining a failure frequency for an aggregate population of dams similar to Jocassee Dam. The NRC calculations used data from 1900 through 2008 and excluded certain dam failures from consideration that would misrepresent the failure rate for earthen or rock filled dams similar to Jocassee. The dam failures excluded were failures of dams less than 50 feet high due to different construction practices for higher dams, dams that failed due to poor design and construction techniques and dams that failed within 5 years of construction. These three exclusions were selected because of common dam industry practice found in dam PRA literature and because NRC agreed that

such failures could affect dam failure data in a non-representative way for Jocassee dam and similar dams. As noted above, the NRC staff did not consider it appropriate to exclude certain failures applicable to Jocassee dam and similar dams. Therefore, the staff did include failures due to overtopping, piping at a conduit passing through the dam, structural failures of the spillway during flood discharge and earthquakes. The NRC staff considered data for rockfill and (post-1940) earthen type dams in calculating a population experience value of 132,8905 operating dam-years. The NRC staff accounted for 25 dam failures (6 rockfill and 19 earthen dams). The resulting dam failure frequency for rockfill and earthen type dams with this population was  $2 \times 10^{-4}$  failures per dam-year, an order of magnitude higher than that reported in NSAC/60.

Similar NRC staff calculations using data for each type of dam design and construction individually resulted in similar values with a  $>10^{-4}$  magnitude dam failure frequency (e.g., rockfill dam failures to rockfill operating dam-years, earthen dam failures to earthen dam operating dam-years, and gravity dam failures to gravity dam operating dam-years). In addition, international dam failure results have been calculated at  $2 \times 10^{-4}$  to  $4 \times 10^{-4}$  per dam-year (Baecher, Gregory, M.E. Pate and R. Neuville. "Risk of Dam Failure in Benefit-Cost Analysis." Water Research. 16(3):449-456. 1980).

Both NSAC/60 and NUREG/CR-5042 are commonly used primary reference documents for licensees performing external flooding analyses incorporating a postulated dam failure, and they have been applied to any type of dam. Readily-available Current dam data, such as from the above-mentioned web sites, are more complete and accurate than data that was available in the 1980s when NSAC/60 was initially prepared. Although there is no specific regulatory requirement to do so, licensees may use this readily-available dam data to develop a facility-specific dam data set or uses of NRC generic rates, when published, in order to update the dam failure frequency value specified in their PRA for external events. As noted previously, this dam data set should appropriately consider probabilities-frequencies for the complete set of potential failure modes. Typically, random internal failures are segregated from external natural phenomena events in both PRAs and deterministic SAR analysis. A dam is not an internal nuclear plant component. Its failure from any cause is considered an external event. The NRC staff considers any failure event, random or natural, which will result in a flood at a nuclear plant must be treated as an external event regardless of the initiating cause.

As new information is gathered and new analyses are completed, dam failure rates may and can be refined. Justification of these refinements should present the basis for the selection of data and the method of analysis. NRR has initiated an action to incorporate dam failure frequency estimates in a future revision of NUREG/CR-6928, "Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants," February 2007, which is a periodically-revised failure rate data reference used by the NRC.

**CONTACT**

This information notice requires no specific action or written response. Please direct any questions about this matter to the technical contact listed below.

Timothy J. McGinty, Director  
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Note: NRC generic communications may be found on the NRC public Web site, <http://www.nrc.gov>, under Electronic Reading Room/Document Collections.

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