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SUPPLEMENT ANALYSIS OF SEISMIC ACTIVITY ON F-CANYON

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Purpose and Scope

The Department of Energy (DOE) issued a *Final Environmental Impact Statement on the Interim Management of Nuclear Materials at the Savannah River Site* (IMNM EIS) in October 1995 (DOE/EIS-0220). DOE has issued two records of decision based on the IMNM EIS regarding stabilization of certain nuclear materials in F-Canyon. Subsequently, new information became available related to the seismic safety analyses which support the IMNM EIS.

The Council on Environmental Quality (CEQ) regulations for implementing the National Environmental Policy Act (NEPA), 40 CFR 1502.9(c), direct federal agencies to prepare a supplement to an environmental impact statement (EIS) when an agency "makes substantial changes in the proposed action that are relevant to environmental concerns, or there are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts."

Under DOE regulations for compliance with NEPA (10 CFR 1021.314), when it is unclear whether or not an EIS supplement is required, DOE is to prepare a supplement analysis to assist in the determination of the need for a supplemental EIS. This supplement analysis has been prepared to evaluate certain new information regarding the effect of a severe earthquake on F-Canyon at the Savannah River Site (SRS), and to compare the new information with the evaluation of earthquake accident impacts presented in the IMNM EIS.

Summary

In October 1995, DOE prepared the IMNM EIS to consider the interim management of certain nuclear materials at the SRS. As described and analyzed in the EIS, DOE proposed to stabilize some of these materials by processing them in the F-Canyon. As part of the analysis, the EIS estimated the amount of radioactive material that could be released from F-Canyon into the environment as a result of a severe earthquake[1].

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[1] The earthquake used in the accident analysis of the IMNM EIS was an event with a response spectrum (a profile of ground acceleration over a range of frequencies of motion) and peak ground acceleration (a fraction or multiple of the acceleration of gravity, measured in "g's"), as defined by J.A. Blume & Associates Engineers (Blume) for the SRS in the early 1980s. A frequency of occurrence (or return period) of once every 5000 years was eventually stated to correspond to the Blume earthquake.

The EIS's estimate of how F-Canyon would perform structurally during such an earthquake was based on data contained in existing Safety Analysis Reports (SARs) (Safety Analysis -200 Area Savannah River Plant F-Canyon Operations DPSTSA-200-10 Supplement-4 and Safety Analysis -200 Area Savannah River Plant FB-Line Operations DPSTSA-200-10 Supplement-9) that, in turn, relied on information developed in the 1980s.

While WSRC was reviewing safety documentation for the H-Canyon at the Savannah River Site, they discovered that the seismic analyses performed in the early 1980s were based on assumptions that were inconsistent with the as-built condition of H-Canyon (e.g., the degree of overlap of reinforcement steel was in some cases less than assumed for the EIS analysis). Because F-Canyon is similar to H-Canyon in both design and construction, this information was regarded by the Department as also applicable to the F-Canyon facilities.

The issue presented by the new information under NEPA is whether the as-built condition of F-Canyon would result in significantly greater radioactive releases due to building degradation as a result of a severe earthquake than are estimated in the IMNM EIS. For DOE to be able to resolve this issue (and the related issue of whether new radioactive materials should be introduced into F-Canyon for stabilization), Westinghouse Savannah River Company (WRSC) had to complete its on-going seismic analysis. In completing its analysis, WSRC not only considered the as-built condition of the Canyon, but also incorporated the most current information available about the probable size and frequency of a severe earthquake in the region where the Savannah River Site is located (WSRCa).

The new seismic analysis was prepared by WRSC with input from its consultants. The engineers and scientists involved in the preparation of the seismic evaluation were experts in their respective fields, and in many cases are nationally recognized for their contributions to the science of seismic and structural analysis.

Using up-to-date seismic data, WSRC completed a detailed evaluation of the likelihood of a severe earthquake and a structural analysis quantifying the likelihood of structural failure[2] of F-Canyon for a range of ground motions. Based on the WSRC evaluation, an earthquake that could occur about once every 8000 years would cause a level of structural damage to F-Canyon similar to the level of damage attributed to the earthquake considered in the IMNM EIS. Additionally, the response spectrum associated with the 8000-year earthquake was determined to encompass (be more severe than) the Blume response spectra. Thus, the capability of the Canyon to survive an earthquake more severe than that evaluated in the EIS, in combination with the fact that the likelihood of this level of damage was less than assumed in the EIS (1/8000 years compared to 1/5000 years), indicates that F-Canyon is seismically as safe as, or safer than, indicated in the IMNM EIS.

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[2]Throughout this document the term "failure," when applied to the new seismic analysis work of WSRC, does not mean building collapse. It means the onset of cyclic strength degradation in the important load-bearing joints of the structure. The onset of cyclic strength degradation is the point where the strength of the structural elements begins to degrade significantly as a result of the cyclic earthquake motion.

Two other comparisons were also made. First, based on the new WSRC structural analysis building models, an estimate was made of the probability of structural failure at the Blume response spectra (i.e., the F-Canyon as-built was subjected to the same magnitude earthquake as analyzed in the EIS). This probability of failure ranged from about 3 percent to 39 percent, which indicated that the current structural evaluation resulted in a lower level of structural damage compared to that estimated in the EIS (equivalent to 50% probability of failure) for the same Blume earthquake. Second, an estimate was made of the probability of failure for an earthquake estimated to have a 5000 year return period based on the new WSRC analysis. In the case of the current 5000 year earthquake, the new WSRC structural analysis building models indicate that the probability of failure is about 4 percent, again a lower level of damage than considered in the EIS. These two comparisons show that the new WSRC structural evaluation predicted a lower level of damage for both the current 5000-year earthquake and Blume response spectra.

Collectively, the foregoing discussion indicates that no matter which comparison is made (i.e., severity of earthquake for the same level of damage to F-Canyon described in the IMNM EIS; the level of damage for the same Blume earthquake; or the level of damage for the current 5000-year earthquake), the seismic risk at F-Canyon, based on the new, more detailed analysis, is lower than that indicated in the EIS.

Current DOE safety requirements specify that facilities like F-Canyon must be able to withstand an Evaluation Basis Earthquake[3] (EBE) of a 2000-year frequency (which would be less severe than the earthquake associated with the Blume spectra used in the IMNM EIS). The WSRC analysis demonstrated that the probability of failure (and therefore collapse) for F-Canyon in an EBE was much less than 1%. Thus, the probability of structural damage from an EBE event would be very low.

The WSRC seismic analysis was evaluated by a team from the DOE Savannah River Operations Office and the DOE Office of Environmental Management (DOEa). This team consisted of federal engineers with expertise in the area of seismic and structural evaluations and consultants from the Earthquake Research Center at the City College of New York. They concluded the WSRC work met the requirements established by DOE for seismic evaluations and that the F-Canyon structure was satisfactory when compared to DOE seismic performance criteria. An independent review of the WSRC analysis was also performed by the DOE Office of Environment, Safety and Health (DOEb). This review team consisted of federal engineering staff with specialties in structural analysis and consultants who are nationally recognized experts in the areas of seismic hazard estimation, geotechnical analysis, structural analysis and failure probability and fragility analysis. The team concluded that the WSRC analysis was technically correct and was based on accepted procedures, published data, current methodologies and engineering principles.

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[3] An evaluation basis earthquake is the earthquake an existing facility must be able to withstand to be in compliance with the requirements of applicable DOE Orders and Standards.

All of the several different analyses described above reach the same conclusion--that F-Canyon, as built, would withstand an earthquake of a magnitude of the Blume spectrum, with less damage than described in the IMNM EIS earthquake analysis, and that there would be no greater releases to the environment than those estimated in the EIS. Thus, DOE estimates that the health effects (expressed as latent cancer fatalities) would not be any greater than those described in the EIS. Indeed, the analyses indicate that the releases could be smaller than those previously analyzed in the IMNM EIS.

Accordingly, the new seismic analyses based on the as-built condition of F-Canyon do not constitute significant new circumstances or information relevant to environmental concerns, and therefore no supplement to the IMNM EIS need be prepared.

Background

A. Description of F-Canyon

Building 221-F, called F-Canyon, is located in the F-Area of the Savannah River Site (SRS). The building was constructed of reinforced concrete in the early 1950's and consists of four interior floor levels and a roof which is the fifth level. The bottom of the 5' thick base-mat (or foundation) is located 20' below grade and the building extends to a height of about 51' above grade to the top of the fifth level. The building is about 850' long and 120' wide and is composed of 18 separate sections, each about 43' long (except section 1 which is 85' long). Each of the 43' sections weighs about 12,000 tons. The exterior walls are over 4' thick at the base of the structure and over 2.5' thick at the roof. The roof slab thickness varies from 2.5' to 3.5'. The interface between each section is an expansion joint which is 1/2" wide. The expansion joints are keyed to fit into one another and are sealed with a pre-molded fill similar to asphalt. In the late 1950's a penthouse structure, called FB-Line, was added on top of F-Canyon. The FB-Line consists of: a two-story reinforced concrete frame structure over sections 2, 3 and 4 of F-Canyon; a one-story reinforced concrete frame structure over a portion of section 5; and a newer two-story structure over a part of section 5 and over sections 6, 7 and 8. The first story of the newer penthouse addition is constructed of reinforced concrete. The second story is a non-seismically resistant structure consisting of steel framing and a metal exterior. The original FB-Line structure is about 70' wide and 33' high, and was constructed in 43' long sections to match the F-Canyon below. The expansion joint interface between each section is similar to the F-Canyon design. The first story of the newer portion of FB-Line is about 21' high and 68' wide, and is constructed in 43' long sections.

In the past, the primary use of the F-Canyon/FB-Line was to chemically dissolve irradiated depleted uranium targets, extract the material which had transmuted to plutonium-239, and then convert the plutonium-239 to metal which was shipped to other DOE sites for use in nuclear weapons production. These activities ceased in the early 1990's and the facilities are now being used to stabilize nuclear material left over from the era of nuclear weapons production.

B. Previous Seismic Evaluations

In 1979 E.I. Dupont De Nemours and Company (DuPont), the government contractor operating the site, hired Engineering Design and Analysis Company (EDAC) to prepare a seismic/structural evaluation of various facilities at the SRS, including F-Canyon/FB-Line. The purpose of this evaluation was to determine how these existing structures would perform in a severe earthquake. Seismic input for the F-Canyon/FB-Line analysis was provided by URS/John A Blume & Associates, Engineers (Blume) in the form of peak ground acceleration (pga) (the largest ground acceleration that would be expected to be measured in the earthquake) and response spectrum (a profile of ground acceleration over a range of frequencies of motion). The input was developed after review and analysis of available geologic, seismologic and seismotectonic data relating to the SRS and the surrounding region within a radius of 200 miles. Blume used data from the 1886 Charleston, South Carolina, earthquake to provide the basis for evaluating the SRS seismic hazard to determine the appropriate level of ground motion in terms of peak ground acceleration (pga) and the appropriate response spectra.

Blume determined the level of ground motion that could be expected in a severe earthquake at the SRS. The peak ground acceleration was estimated to be 0.2g. Blume also reported that, based on a probabilistic analysis, the estimated average (mean) annual rate of exceedance of the 0.2g peak ground acceleration was about 10^{-4}. In other words, Blume indicated that the 0.2g pga would be exceeded on average about once in 10,000 years.

The Blume response spectrum was prepared using statistical analyses of ground motion data that matched both SRS geologic conditions as closely as possible, as well as epicenter distance and magnitude for near (within about 25 km of the SRS) and far (within about 145 km of the SRS) events. However, no return period was assigned by Blume to this theoretical earthquake. The response spectrum and the 0.2g pga were used as input for the EDAC structural evaluations of F-Canyon and FB-Line.

The Blume study adequately represented the state of knowledge in the early 1980s. However, the Blume response spectrum is now acknowledged by seismic experts to be biased toward low frequencies as a result of the use of western U.S. data, i.e. the higher frequencies of the response spectrum are not adequately represented. Moreover, the Blume ground motion estimates did not account for any site-specific soil or rock data from the SRS.

At about the same time the Blume input was being developed, probabilistic seismic hazard curves (a statistically based prediction of ground motion) were being developed for all DOE sites (circa 1984). These curves showed that at SRS a peak ground acceleration of 0.19g was associated with a probability of occurrence equal to $2x10^{-4}$ per year, i.e., an earthquake which generates a peak ground acceleration with a frequency of occurrence of once every 5000 years.

Using the seismic information assembled by Blume, EDAC performed a structural analysis to determine the performance of the buildings during the Blume earthquake. For the purposes of EDAC's structural analysis, the seismic performance criteria for the structure would be met if no local or global collapse mechanism was formed or there would be no loss of support from any critical structural member. The performance critieria permitted the yielding, but not collapse, of structural supports. In the EDAC analysis a "mechanism" was defined as the physical situation where there was yielding at a sufficient number of locations, so that the structure would absorb energy beyond the elastic range or beyond the point at which the structure would return to its original shape and integrity. A "collapse mechanism" was defined to occur when excessive lateral force caused allowable ductility ratios (a ratio that describes the capability of material to deform without failing) in reinforced concrete members to be exceeded causing the displacements of the structure to become excessive such that collapse was possible. The EDAC analysis concluded that localized points of failure could occur, but the structure would marginally meet this no-collapse criterion. In other words, the structure would marginally stay within the inelastic response region defined by the allowable ductility ratios for the materials of construction. Although the EDAC analysis does not define the term "marginally," based on EDAC's definition of "collapse mechanism," the level of ductility reached in the structure, and the material strength, it is reasonable to conclude the Blume earthquake would induce the on-set of cyclic strength degradation in F-Canyon. The EDAC analysis predicted the damage would include the sagging of some floor slabs and localized crushing in some columns. The predicted damage could also include concrete cracking at the locations where ductility ratios exceeded 1, such as canyon interior and exterior walls. Additionally, EDAC postulated that the keyed expansion joint between each canyon section could be damaged. The current analysis has assumed that the above description of damage is consistent with a 50% probability of failure. This assumption is conservative considering that the 50% probability of failure in the current analysis is the point where the first joint significantly degrades, but well before the point that the building would collapse.

In 1986, DuPont prepared safety analysis reports (SARs) for F-Canyon and FB-Line to describe facility design and operation and to define the radiological impacts to the workers and the public which could occur from a range of accidents associated with facility operations. The impact to the public was described in terms of risk which was the product of the accident consequences and the frequency of the event. Among the accidents analyzed in the SARs was an accident precipitated by the Blume earthquake. The results of the EDAC analysis were used to help derive accident consequences. EDAC's statements of potential damage to the structure were considered in determining whether the canyon could provide radioactive material confinement in the event a severe earthquake occurred. For the purposes of the SAR, the frequency of the earthquake was taken from the new seismic hazard curves developed in 1984. Thus the frequency of the Blume event (both spectra and pga) was stated to correspond to a frequency of once in 5000 years.

C. IMNM EIS

In 1995 DOE prepared the IMNM EIS to evaluate alternatives for stabilizing nuclear materials which are in storage at the Savannah River Site. Among the alternatives evaluated was the operation of F-Canyon and FB-Line to stabilize various solutions and other material (e.g., Mark-31 targets and plutonium metals and oxides). The evaluations included an estimate of the impacts from earthquake accidents involving F-Canyon and FB-Line. The basis for the earthquake impact estimates in the EIS was the radioactive material release mechanism described by each facility SAR (which was based, in part, on information from the EDAC analysis). On December 12, 1995, DOE decided to stabilize some nuclear materials, including Mark-31 targets, using the F-Canyon/FB Line facilities.

Discussion

A. Chronology of Events

In the Fall of 1995 WSRC began work on a new structural analysis for H-Canyon to support the preparation of an updated H-Canyon Safety Analysis Report. The purpose of the structural analysis was to determine the performance of the canyon using a site-specific earthquake developed in accordance with the latest DOE criteria and state-of-the-art seismic and structural analysis models. Due to similarity in facility design, DOE also considered this work to be applicable to F-Canyon. HB-Line and FB-Line were included in the analysis since the B-Lines are located atop the respective canyons.

WSRC reviewed the EDAC analysis and the seismic criteria established by the Blume study and determined a new analysis was required principally because DOE had issued a new natural phenomenon hazards mitigation Order (and Standards). The new Order and the Standards specified more prescriptive requirements for seismic evaluations than were applicable at the time of the EDAC and Blume studies. These requirements are contained in DOE Order 420.1 "Facility Safety" and a series of five DOE Standards. In accordance with these new requirements, F-Canyon and FB-Line were classified as performance category 3 (PC-3) structures for the purpose of seismic evaluations. Based on this classification, DOE requirements specified the EBE would be a once in 2000-year earthquake and the target performance goal for a PC-3 facility would be a once in 10,000-year earthquake (hereafter referred to as the seismic margin event or SME). Additionally, the earthquake ground motion was to be described by probabilistically-derived site-specific seismic hazard curves.

By January 1996, a conservative preliminary analysis by WSRC had determined that canyon performance in the event of a postulated site-specific earthquake might be less favorable than expected. These preliminary results prompted WSRC to review the EDAC analysis since the EDAC analysis had concluded canyon performance in a severe earthquake had marginally met the EDAC criteria. On February 29, 1996, WSRC notified DOE of the potential inadequacy in the structural analysis that supported the authorization of activities to be conducted in the canyons. Specifically, WSRC determined that some of the building joint capacity assumptions in the EDAC analysis were not supported by actual building design details (e.g. the embedment and splice lengths of the reinforcing bar into the concrete was less than assumed). WSRC expected to resolve the question by completing new structural analyses.

On March 15, 1996, then Assistant Secretary for Environmental Management, Thomas P. Grumbly, approved a staff recommendation to continue stabilizing material already in F-Canyon and H-Canyon while awaiting the results of the WSRC analysis work, but to prohibit the introduction of any new material into the canyon for stabilization purposes.

On June 4, 1996, Mr. Grumbly, now the Under Secretary, requested a review of the WSRC seismic analysis by the Office of the Assistant Secretary for Environment, Safety and Health (EH). On June 21, 1996 the Assistant Secretary for Environment, Safety and Health committed a team of EH personnel and expert consultants to accomplish a detailed review after completion of the WSRC analysis.

WSRC's first step toward completing the new seismic analysis was to define the ground motion for the EBE and SME. WSRC accomplished this by defining the bedrock motion caused by the earthquakes and analyzing how this bedrock motion would be transmitted to the surface through soil columns with properties based on empirically-derived soil data (i.e., from actual soil tests). The bedrock motion was derived using probabilistic seismic hazard assessments conducted by the Electric Power Research Institute (for commercial utilities) and Lawrence Livermore National Laboratory (for the U.S. Nuclear Regulatory Commission), that were specifically applicable to the SRS. The seismic hazard data from these studies were averaged and revised to derive uniform hazard spectra (UHS) (i.e., prediction of ground acceleration over a range of frequencies of motion) for bedrock at the SRS at annual probabilities of $5x10^{-4}$ (1/2000 years) and $1x10^{4}$ (1/10,000 years). The spectral shapes (ground motion curves) were developed for the 1/2000 year, the EBE, and 1/10,000 year, the SME, for F-Canyon and FB-Line. As a final step in developing rock motion data a check was performed to ensure the probabilistically-derived EBE was adequately conservative for historical earthquakes within 200 km of the SRS (e.g., the Charleston earthquake of 1886).

With the ground motion defined, the last part of the seismic evaluation was to perform a structural analysis of the facilities. For an existing facility such as F-Canyon or FB-Line, DOE Standard 1020-94 specifies that the facilities could be evaluated against current design or "code" requirements, even though the facilities were already built and were designed to earlier code requirements. Alternatively, the building could be evaluated by determining its seismic adequacy (i.e., the inherent strength) in its as-built condition. In the code based assessment, the general acceptance criteria required that the facility remain elastic at the EBE. In the seismic adequacy assessment, the acceptance criteria required that the structure not fail with a specified degree of certainty, i.e., less than a 10% probability, after the EBE's effect on the structure had been increased by a factor of 1.5.

The seismic adequacy assessment method was applied to the evaluation of F-Canyon and FB-Line. The code assessment method was not applied since it relies on design specifications that did not exist as code requirements at the time of original construction and because as-built conditions and empirical data on structural performance could not be factored into the code analysis. The F-Canyon and FB-Line were also evaluated against the performance goal established by DOE Standard 1020-94. The Standard specifies a mean probability of failure of $1x10^{-4}$ for facilities such as F-Canyon, but allows for a slight increase in the average or mean probability of failure when an existing facility is close to meeting the performance goal.

In order to perform the F-Canyon and FB-Line structural evaluation, WSRC reviewed the design of these facilities as well as the design of H-Canyon and HB-Line to determine their most limiting structural design features, so that the bulk of the analysis work would be applicable to both canyons. Analysis showed section 6 of H-Canyon to be controlling (i.e., the most vulnerable to damage in an earthquake) thus the final results discussed below are based on the analysis of section 6 of H-Canyon. WSRC performed the structural evaluation using non-linear dynamic analysis methods (methods which are used to evaluate inelastic structural behavior) to determine the effect of the EBE and SME on the F-Canyon and FB-Line. Actual material strengths, based on samples from the structures, were used in the calculations.

The objectives of the analysis were to evaluate the capability of the structures at the EBE and to determine the mean probability of failure of the structure in terms of maximum lateral drift (i.e., the relative displacement between the roof of the structure and the foundation), the ground motion for these drifts and the probability of the onset of cyclic strength degradation. The maximum lateral drift was established by relating drift with the amount of rotation allowed at structural joints in the buildings. The results from this work were then used to compare the performance of the building against the DOE Standard 1020-94 criteria.

WSRC concluded that the structure met the criteria established in DOE Standard 1020-94 for an existing facility. The building drift was calculated as 3.2 inches. This corresponded to about 1% probability of failure which was well within the DOE requirement that existing buildings must be within a 10% probability of failure. In order to evaluate facility performance against the second criterion (a mean annual probability of failure equal to approximately $1x10^{-4}$), analyses were performed to develop a fragility curve, i.e., a prediction of failure probability versus the severity of an earthquake. This curve was constructed based on the failure probability and performance information associated with the EBE and SME. The results of this work indicated the mean annual probability of failure for the F-Canyon would be equal to $1.2x10^{-4}$. This equated to an earthquake return period of about 8,000 years. WSRC also determined the peak ground acceleration for the 8,000 year earthquake to be 0.24g.

WSRC estimated that the potential building lateral drift was about 6" at the mean annual probability of failure. WSRC determined that at this lateral drift, horizontal cracking could develop in the concrete at each exterior wall-to-roof joint and at each exterior wall at about the first-level ceiling elevation in the canyon. The cracks would be irregular and would not form line-of-sight pathways through the walls since the cracks would be under compression from the weight of the structure. Additionally, there was the potential for limited failure at each expansion joint key between each of the 18 segments comprising the canyon. The failure of the joint key, combined with potential displacement of joint filler (due to transverse movement of the canyon sections) could result in localized 1/2" gaps occurring within the expansion joints. After further evaluation, WSRC determined that the expansion joint key on the west side of the canyon was a single tongue and groove arrangement and that the key on the east side of the canyon was constructed using a saw-tooth design. The thickness of the canyon walls ranged from 30" on the west side to 48" on the east side. The saw-tooth key substantially increased the ability of the expansion joints to resist relative transverse movement. WSRC calculated the relative maximum transverse displacement between sections would be no more than +/-0.70" under the seismic loading created by the SME because of the strength of the saw-tooth joints. The maximum relative displacement of the building would occur at the roof-to-exterior-wall interface and diminish to zero inches of displacement at a distance measured 37' down the wall from the roof. Because of the strength of the saw-tooth joint, WSRC concluded the likelihood of any loss of the pre-molded filler would be minimal on the east side or top of the canyon and that no significant loss would occur on the west side.

Two additional analyses were conducted by WSRC to relate current estimates of structural damage to that assumed in the EIS. First, WSRC performed a study using time-histories (a prediction of ground acceleration over time) with acceleration response spectra that closely matched and typically exceeded the Blume response spectra. These time-histories were run through the same structural analysis models used to evaluate the site-specific earthquake. The results showed the maximum building roof displacement from the Blume spectra was less than that calculated using the site-specific spectra, and that the probability of failure for the Blume related time-histories was between 3% and 39%. The results for the Blume spectra indicated the Blume earthquake was less severe than the 8000-year earthquake used by WSRC in the new analysis of F-Canyon and FB-Line, and that these facilities have a higher seismic survival capacity (and therefore would be subject to less damage) than that assumed in the IMNM-EIS. Based on the estimated displacements for a 5000-year earthquake, and using the structural fragility curve, the probability of failure associated with a once in 5000-year earthquake is about 4%, which indicates a lower level of damage would occur at this return period than was estimated in the IMNM EIS where it was assumed to be about a 50% probability of failure.

On July 12, 1996, a joint DOE-SR and Office of Environmental Management (EM) review team completed an evaluation of the WSRC analysis effort [DOEa]. The review team had established 17 acceptance criteria for their evaluation based on DOE Order 420.1 "Facility Safety" and associated Standards. The review team determined all acceptance criteria were satisfied and concluded the following: F-Canyon had relatively small displacements at the EBE with a very low probability of failure; the 8000-year earthquake was equal to or more severe than the 0.2g Blume response spectra (used in the original analyses); the mean probability for failure of the structure was 1.25×10^{-4} per year; and from a building collapse perspective, the F-Canyon met the criteria established in DOE-STD-1020-94 for an existing facility. The review team did not identify any technical issues that required resolution before the resumption of F-Canyon stabilization activities. The team did note one issue concerning some column concrete samples with compressive strengths that were below design strength specifications. However, the team stated that lower strength values had been accounted for in all the WSRC calculations and that the columns were shown to be adequate given the reduced strength. As a follow-up to the review team report, additional sample testing of the columns was initiated to determine the cause of the low concrete strength. The Army Corps of Engineers conducted the tests and determined the low strength of the concrete was likely to have been the result of original construction and was not due to on-going deterioration.

Additionally, the DOE-SR/EM review report provided a comparison of the Blume spectrum to the spectrum associated with the mean annual probability of failure of F-Canyon (i.e., the mean fragility response spectra). In this comparison, the mean fragility response spectra encompassed the Blume spectra for the range of frequencies of concern for F-Canyon and FB-Line [DOEa]. In other words, the spectrum estimated for an earthquake with an 8000-year return period was more severe than the Blume spectrum. The mean fragility spectra were calculated by scaling down the spectra associated with the SME. This was a reasonable approach since the relationship between the two events is linear when comparing the mean annual probability of each.

On August 19, 1996 the Office of Environment, Safety and Health issued its evaluation (EH review) of the WSRC seismic analysis calculations [DOEb]. The EH review was conducted in four technical areas: 1) the seismic hazard estimation, 2) the geotechnical analysis, 3) the structural analysis, and 4) the failure probability and fragility analysis. The review team was comprised of federal personnel and nationally recognized experts in each of these four areas. After an initial review of the overall WSRC work, the team concentrated its efforts on the approach WSRC used to model the slip of reinforcing steel bar in concrete and the performance and validation of structural analysis models. The team also carefully reviewed the treatment of the expansion joints at each building segment and reviewed the fragility and probability analyses. In performing their independent review, the team noted conservatisms in the WSRC analysis. In addition, the team conducted independent structural modeling and calculations. This activity produced results for building drift that were similar to the WSRC results. The team concluded that the WSRC analysis was based on accepted procedures, published data, current methodologies and engineering principles and was technically correct.

B. Comparison of Analysis Results to IMNM EIS

The IMNM EIS earthquake accident analysis impacts were based on the amount of radioactive material that could be released from F-Canyon/FB-Line as predicted in the existing Safety Analysis Report for these facilities. The following accident sequence was analyzed: the earthquake occurred during operations which involved transfers of radioactive solutions involving 10 of the largest tanks inside the canyon. The force of the earthquake caused the transfer piping to leak and the contents of the tanks were pumped out onto the canyon cell floor. A portion of the spilled material evaporated inside the canyon and some of the airborne material (estimated to be 10%) made its way outside to the environment through cracks in the canyon structure caused by the earthquake. The material released outside the canyon was then assumed to be blown off-site to the general population. This scenario is very conservative because it tended to overstate the risk in several respects. For example, it assumed an earthquake with a projected frequency of once every 5000 years actually occurred during the remaining operating life of the facility. Additionally, the scenario assumed an earthquake powerful enough to crack the walls of the canyon and rupture stainless steel piping would not interrupt steam or electrical power, therefore allowing the contents of 10 tanks to be pumped to the canyon floor (an interruption in steam and electrical service would disable pumping capability). Also, the scenario assumed all of the material released from the facility was accumulated at essentially one point outside the facility and that it was blown off-site in a narrow plume. The plume was assumed to have maintained essentially a straight line that extended from the release point to the nearest off-site location (a distance of several miles). During the transit off-site, there was effectively no deposition or dispersion so that the concentration was essentially undiluted. The amount of material released in the accident analysis for the IMNM EIS was estimated to be 10% of the airborne radioactive material in the building. It should be noted that it is extremely unlikely all of these conditions would (or could) actually occur.

The level of damage to the walls would affect the amount of radioactive material that could be released outside the facility. The level of damage predicted for the earthquake accident, as indicated in the IMNM EIS, was based on descriptions of damage in the EDAC report, i.e., sagging of some floor slabs and localized crushing of some columns. It could also be concluded that concrete cracking would be expected at locations where ductility ratios exceeded 1, such as canyon interior and exterior walls. Additionally, it was postulated that the keyed expansion joint between each canyon section could be damaged. Thus, the damage state associated with the EDAC analysis is a significant amount of cracking, but not structural collapse.

The new WSRC analysis indicated that an earthquake more severe than the Blume event would cause a similar level of damage to the canyon and that the Blume event, or an event which occurred once every 5000 years, would cause less damage to F-Canyon than that indicated in the analysis for the IMNM EIS. In both the original and new analysis the cracks in the walls were considered to be irregular and would not form line-of-sight pathways for direct leakage. As a result, it was reasonable for the new WSRC analysis to conclude that the amount of material assumed to be released would be no greater than that released under the original analysis. As an additional check, WSRC performed a calculation to estimate the volume of canyon air loss (in %) which could be expected to be released as a result of the damage predicted from the most severe earthquake associated with the new analysis. WSRC calculated the air loss to be about 7% (compared to the 10% release of airborne radioactivity estimated in the EIS). Since the volume of air released is a reasonable surrogate for the amount of airborne radioactive material which could be released, the WSRC analysis shows less radioactive material would be released in a severe earthquake than that indicated in the IMNM EIS analysis.

The IMNM EIS provided health impact information for the earthquake accident scenario in terms of consequence and risk. Consequence was described in terms of the number of increased latent cancer fatalities which could be expected from public or worker exposure to the radioactive material released during the accident. The potential health impacts (i.e., consequences) portrayed in the IMNM EIS would not be increased because no more radioactive material would escape than previously estimated. Risk in the IMNM EIS was derived by multiplying the frequency of the earthquake by the calculated consequences from the accident. The earthquake frequency in the IMNM EIS was assumed to be a one in 5000-year event ($2x10^{-4}$ per year). Risk would not be increased since the frequency of the new earthquake (for the level of damage described) was a one in 8000-year event ($1.25x10^{-4}$ per year). The lower frequency multiplied by the same consequence results in less risk.

Conclusions

The earthquake accident consequences presented in the IMNM EIS continue to be representative of expected impacts since the canyon structural integrity, estimated on the as-built condition of the canyon, would be equal to or better than that relied upon by the accident analysis in the IMNM EIS. That is, based on the new, more detailed analyses, the structure would achieve the same (or better) level of radioactive material confinement estimated in the earthquake accident analysis for the IMNM EIS. Earthquake accident consequences in the EIS are a function of the structural confinement capability. Since the confinement capability has not been reduced, the consequence from the accident would not increase. Indeed, the new seismic analysis indicates that potential releases from an earthquake of the magnitude of the one analyzed in the EIS would be smaller than those predicted in the EIS.

The earthquake risks presented in the IMNM EIS continue to be representative of the potential impacts that would be calculated using the new canyon structural response information. The severe earthquake (peak ground acceleration) used in the IMNM EIS analysis was predicted to occur no more than once every 5,000 years, while the new analysis predicted an earthquake which causes a similar level of damage would occur with less frequency i.e., once every 8,000 years. The risk associated with impacts from earthquake accidents in the IMNM EIS was the product of earthquake frequency and potential consequences. Since the consequences (i.e., the number of latent cancer fatalities) would be no greater and the frequency of the severe earthquake is less, the recalculated risk is less than those currently represented in the IMNM EIS.

The new information associated with the structural response of F-Canyon and FB-Line does not depart significantly from the information contained in the IMNM EIS. This new information also does not present a seriously different picture of environmental consequences than those projected in the EIS. Accordingly, the new seismic analyses based on the as-built condition of F-Canyon do not constitute significant new circumstances or information relevant to environmental concerns, and therefore no supplement to the IMNM EIS need be prepared.

References

DOEa. F-Canyon Seismic Analysis Safety Evaluation, July 1996.

DOEb. DOE EH-0529, Independent Review of the Seismic Analyses for the F-Canyon at the Savannah River Site, August 1996.

WSRCa. Westinghouse Savannah River Company Inter-Office Memorandum, ECS-MSM-96-009, Summation of Results of the Structural Evaluation of F-Canyon Building 221 (U), July 8, 1996.