96-0003041

Department of Energy

Washington, DC 20585

July 31, 1996

The Honorable John T. Conway
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, NW
Suite 700
Washington, D.C. 20004

Dear Mr. Chairman:

Enclosed is a memorandum which constitutes Headquarters action on the Savannah River Site "Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility." Site completion and Headquarters review and action for this performance assessment are deliverables pursuant to the commitment in Task Initiative VII.B.5.b.1 identified in the Department of Energy's (DOE's) Implementation Plan, Revision 1, for the Defense Nuclear Facilities Safety Board Recommendation 94-2.

The assessment evaluates the performance of the Saltstone Disposal Facility relative to the low-level waste performance objectives contained in DOE Order 5820.2A. The Headquarters review found that, with conditions, the assessment is technically acceptable and provides a reasonable expectation of meeting the DOE Order 5820.2A performance objectives, in all areas except groundwater protection. The information available was judged insufficient for Headquarters to draw a conclusion on compliance in this area. The site has been requested to provide by August 30, 1996, a schedule for when the information needed will be provided or written justification explaining how previously provided information is technically and legally sufficient.

The Department has taken action on the Saltstone Disposal Facility performance assessment, however the commitment is not considered complete. We will provide the revised schedule for completing the evaluation and issuing the memorandum addressing acceptability of this performance assessment after we receive the information requested from the site.

Sincerely,

Alvin L. Alm

Alvin L. Alm
Assistant Secretary for
Environmental Management

Enclosure

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MISSING IMAGE

Please provide by August 30, 1996, either a schedule for when you will provide the information needed to complete the evaluation, or written justification explaining how previously provided information is technically and legally sufficient.

For your information our draft compliance evaluation of the performance assessment is included as an Attachment 1 to this memorandum, along with the draft conditions, Attachment 2, we intend to impose for conditional acceptance, excluding groundwater protection.

Consistent with the "Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 94-2 Implementation Plan, Revision 1," (April 1996) full approval of the performance assessment will not be contemplated until the completion of a composite analysis which evaluates the potential offsite radiological impacts of the Saltstone Disposal Facility in conjunction with other radioactive sources that will remain at the Savannah River Site. Upon satisfactory completion of the composite analysis and approval by HQ, the performance assessment will be approved and a disposal authorization statement issued.

If your staff has any questions regarding this memorandum they should contact Virgil Lowery of my staff on (301) 903-7142.

Mark W. Frei for

Stephen P. Cowan
Deputy Assistant Secretary
for Waste Management
Environmental Management

Attachment

Predecisional Draft

Attachment

Compliance Evaluation of the "Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility," WSRC-RP-92-1360, December 1992.

1.0 Summary

The Office of Planning and Analysis (EM-35) concludes from its review of the "Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility" (PA), additional information provided by Savannah River Site personnel after the PA was submitted, and the Performance Assessment Peer Review Panel report, that there is a reasonable expectation that the Order DOE 5820.2A low-level waste performance objectives will be met. The analyses presented in the PA and supplemental documentation result in the following conclusions relative to the performance objectives:

- The all-pathways doses for either intact or degraded (cracked) vaults will be less than the performance objective of 25 mrem/yr based on meeting a 4 mrem/yr performance target for drinking water only (see below) since this is the most significant pathway.

- The air pathway performance objective of 10 mrem/yr for an offsite receptor will be met based on an extremely conservative analysis that resulted in a calculated dose of 10 mrem/yr via the air pathway for a person residing 15 cm above exposed saltstone, in a confined space, for a complete year.

- Dose to a hypothetical intruder from chronic exposure is calculated to be 0.6 mrem/yr versus a performance objective of 100 mrem/yr. Dose from acute exposure is expected to be less than that from chronic exposure so the 500 mrem/yr performance objective will be met.

- [Insufficient information to complete evaluation of the "protect groundwater" performance objective. Available information supports the all-pathways performance objective]

  Doses from intact and degraded vaults and saltstone are calculated to be 0.001 mrem/yr and 0.6 mrem/yr, respectively, via the drinking water pathway versus an assumed performance target of 4 mrem/yr for radionuclides migrating from the disposal facility. Maximum doses during the 1000 year compliance period are not reported, therefore, the reported peak doses which occur beyond 1000 years are used to evaluate compliance.
  Sensitivity/uncertainty analyses were conducted by identifying the

modeling parameters to which the results were most sensitive, and individually evaluating the impacts of using higher and lower input values than those used for the base cases or by using a statistical method that samples multiple parameters and tests various combinations. Those parameters with the greatest impact resulted in calculated doses higher by a factor of up to 300. This result of a conservative sensitivity/uncertainty calculation, considered in light of the other conservatisms employed in the modeling, is judged to be consistent with a reasonable expectation that the performance target for protecting groundwater will be met. However, it does emphasize the necessity to conduct a maintenance program aimed at reducing uncertainties in the values of input parameters and the modeling results.

The PA included analysis of the migration and groundwater concentration of nitrates. Since the nitrates are not radioactive, they are not considered in this compliance evaluation.

2.0 Performance Measures

2.1 Performance Objectives

This evaluation is developed in relation to the requirement in Order DOE 5820.2A, Chapter III, 3.b.(1), which states, "Field organizations with disposal sites shall prepare and maintain a site specific radiological performance assessment for the disposal of waste for the purpose of demonstrating compliance with the performance objectives stated in paragraph 3a." The performance objectives for low-level waste management (III.3.a) are:

(1) Protect public health and safety in accordance with standards specified in applicable EH Orders and other DOE Orders.

(2) Assure that external exposure to the waste and concentrations of radioactive material which may be released into surface water, ground water, soil, plants and animals results in an effective dose equivalent that does not exceed 25 mrem/yr to any member of the public. Release to the atmosphere shall meet the requirements of 40 CFR 61. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as reasonably achievable.

(3) Assure that the committed effective dose equivalents received by individuals who inadvertently may intrude into the facility after the loss of active institutional control (100 years) will not exceed 100 mrem/yr for continuous exposure or 500 mrem for a single acute exposure.

(4) Protect ground water resources, consistent with Federal, State and local requirements.

Consequently, the PA is reviewed and evaluated primarily to determine whether it provides a reasonable expectation that the above-listed performance objectives will be met. The determination involves comparison of the results of the cases analyzed with the performance objectives. The sensitivity/uncertainty analyses are evaluated to ensure that the cases analyzed are reasonably conservative (i.e., the values of the parameters selected for the cases analyzed are in the conservative portion of the range of applicable values and results of the cases analyzed are in the upper range of results from the sensitivity/uncertainty analyses, but are not at the highest end of the range). Also, the results of the sensitivity/uncertainty analyses, taken together, should indicate that it is likely that the performance objectives will not be exceeded (i.e., results of the sensitivity/uncertainty analyses lie below as well as above the cases analyzed).

2.2 Interpretation and Other Criteria

This section addresses how some of the performance objectives are interpreted and applied in the evaluation of the performance assessment and also other criteria that are used in the evaluation. Certain criteria, assumptions or practices used in the preparation of the Saltstone PA were based on best judgment of the analyst and recommendations of the DOE Performance Assessment Task Team due to the lack of specific policies or guidance (e.g., time of compliance, intruder analyses). Most of the subjects for which policies or guidance were lacking are now being addressed by DOE. The judgment and guidance used at the time the PA was prepared was consistent with or tended to be more conservative than the policy and guidance now being contemplated.

The Order DOE 5820.2A is silent on the time of analysis and time of compliance. Consistent with DOE's documented position (e.g., letter, T. O'Toole (EH-1) to Mary Nichols (EPA), June 13, 1995), this compliance evaluation has focused on compliance for times not to exceed 1000 years for the all pathways and groundwater protection analysis. In the absence of specific guidance, the PA analysts conservatively extended these analyses to the time of peak dose. Since the analyses were performed when there was no direction on the time of compliance, the analysts did not report results at 1000 years. Therefore, results at the 1000 year time of compliance are inferred from the reported results. This compliance evaluation considers the analyses beyond 1000 years as support to the reasonableness of the modeling.

The point of compliance for scenarios evaluating dose to an offsite receptor is taken to be the point of maximum exposure at or beyond 100 m from the edge of the waste, which is well within the current Savannah River Site boundary.

Evaluation of dose via the air pathway is to be in accordance with 40 CFR 61, Clean Air Act regulations. These regulations specifically exclude radon from the dose evaluation. This practice is used in the air pathway analysis and extended to the all-pathways analysis. Radon is evaluated separately using the ground surface flux limit borrowed from the Uranium Mill Tailings regulations. Acceptable limits for disposal or evolution of radon in the disposal facility are based on a flux limit of 20 pCi/m^2/s at the ground surface.

For intruder analyses, in this evaluation it is assumed that a hypothetical, temporary intrusion into the waste site occurs shortly after 100 years, the assumed time of active institutional control in Order DOE 5820.2A. The time of intrusion can be extended based on passive controls such as disposal system design or land use controls.

In this evaluation, the reasonableness of intruder analyses is based on current DOE thinking which places less emphasis on intruder analyses because of the intent to maintain permanent institutional control of contaminated lands. Instead the focus is on selecting reasonable scenarios and reasonably conservative parameter values. Thus, although in the Saltstone performance assessment sensitivity/uncertainty analyses were performed on selected parameter values, they were not needed to assess compliance with intruder performance objectives.

In this evaluation of the intruder analyses, doses to the intruder are assumed to come from the exposure to, and ingestion and inhalation of, material exhumed from the site. This may occur via a variety of pathways, but the analysis is not expected to include consumption of contaminated groundwater. The impacts of groundwater contamination are evaluated with respect to the all-pathways and groundwater protection performance objectives.

A tiered approach is now used in determining compliance with the groundwater protection performance objective. The first tier is compliance with applicable federal, state, or local regulations for groundwater protection from the low-level waste disposal facility. The second tier is compliance with negotiated agreements. The final tier of the groundwater protection protocol is for sites to be consistent with their groundwater protection plan as developed under Order DOE 5400.1. This PA predates the development of the tiered groundwater protection guidance.

3.0 <u>Technical Adequacy Review</u>

One of the functions performed by the DOE Low-Level Waste Performance Assessment Peer Review Panel (PRP) is a preliminary review of a performance assessment while it is in draft form. The PRP reviewed the subject PA and provided comments for consideration. In finalizing the PA the site considered and responded to these comments. The resolution of the comments is addressed in Appendix G of the PA.

Upon submittal of the current version of the PA, Headquarters requested that the PRP conduct a review of the PA for consistency and technical quality. Over the course of 5 months, the PRP completed its review. The PRP reported the results of its review in the letter, W.E. Kennedy, Jr. to J.A Coleman, "Performance Assessment (PA) Peer Review Panel (PRP) Recommendations on the Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility," (WSRC-RP-92-1360, December 18, 1992, Rev. 0), August 19, 1993. In the course of its review, the PRP requested additional information or analyses from the Savannah River Site personnel. The site provided an unsolicited set of supplemental information and two supplements were provided in response to PRP requests; these supplements constitute part of the basis for the PRP's finding that the PA is technically acceptable.

4.0 <u>Disposal Facility Performance</u>

Disposal facility performance relative to the performance objectives is discussed below. An abbreviated restatement of the performance objectives is given in italics. These correspond to the performance objectives listed in Section 2.1, Performance Objectives.

The disposal facility addressed by this PA comprises up to 15 concrete vaults that do or will contain salt solution that has been solidified with a combination of slag, fly ash and cement. Most of the vaults are 60m by 180m by 7.6m high, divided into 12 30m by 30m cells. One of the vaults is composed of 6 cells and is half as wide as the other vaults. These vaults are permitted as an industrial waste landfill by the State of South Carolina.

The closure concept for this facility involves a layered barrier over the saltstone vaults that incorporates drainage layers intended to route infiltrating water to an array of drainage channels that will move the water away from the Saltstone Disposal Facility. The barrier includes a clay and gravel barrier immediately on top of the vaults, an upper drainage barrier above that, then top soil that is to be planted with a shallow-rooted bamboo. The plant cover is to reduce the rate at which the surface would be eroded by runoff and to inhibit the growth of deeper-rooted plants that have a greater potential of transporting radioactivity to the surface. The plant cover also reduces the amount of infiltration by recycling water back to the atmosphere by transpiration.

Section 2.3 of the PA describes the source of waste to be disposed of at the Saltstone Disposal Facility. The principal feed stream is a salt solution resulting from the In-Tank Precipitation process used to treat high-level waste. The other feed stream is waste water arising from the F/H Areas Effluent Treatment Facility. The projected inventory of radionuclides to be disposed of in the Saltstone Disposal Facility is presented in Section 2.6 of the PA.

Acceptance of the following results is predicated on technically valid analyses having been performed. The PRP has reviewed the PA, and supplemental information, and determined that they were technically acceptable. However, acceptable performance of the Saltstone Disposal Facility has been shown to be dependent on the functioning of the gravel/clay barrier on top of the vaults (Letter James R. Cook to William E. Kennedy, Jr., "Response to Request for Additional Information for SRS Saltstone Performance Assessment (U), SRT-WED-93-0187, May 17, 1993.) Therefore, based on the analyses presented, it is imperative to the success of Saltstone disposal that the closure concept be further developed and field tested to demonstrate that the necessary barrier performance can be achieved.

4.1. *Protect public health in accordance with applicable DOE Orders.*

Compliance with Order DOE 5400.5 is not a required part of this evaluation. Regardless, from the standpoint of planning, it is useful to consider the results of the Saltstone Disposal Facility PA in relationship to the public radiation protection standards of 100 mrem in a year via all pathways and 10 mrem in a year via the air pathway as contained in Order DOE 5400.5. A comparison of PA results with these public protection standards provides confidence that corrective actions will not be needed in the future to ensure that doses to the public will be maintained at low levels. As discussed below, the PA projects no difficulties in meeting these standards in the future.

The PA shows peak doses occurring in the distant future. It is assumed that at the time that the peak doses are projected to occur, the only contributors to dose will be the closed facilities that remain at the site. These will include waste that has been disposed of (e.g., DOE disposal facilities, commercial disposal facilities) and residual radioactivity disposed of in place from environmental restoration activities. Order DOE 5820.2A establishes an all-pathways effective dose equivalent limit of 25 mrem/yr to a member of the public. Therefore, projected compliance with the Order DOE 5820.2A shows that the 100 mrem/yr limit will easily be met <u>for the Saltstone vaults by themselves.</u>

The Department has committed to preparing a composite analysis that evaluates the impacts of the other sources that add to the dose resulting from low-level waste disposal facilities. The Savannah River Site is scheduled to complete a Composite Analysis which considers the effects of the Saltstone Disposal Facility and other facilities on an offsite hypothetical member of the public (see the DNFSB 94-2 Implementation Plan, Revision 1, April 1996). That analysis is to be reviewed and approved by Headquarters prior to issuing a disposal authorization statement for the Saltstone Disposal Facility.

Compliance with the air pathway limit of 10 mrem/yr is also included in the performance objectives of Order DOE 5820.2A, Chapter III and will be addressed below.

4.2 ***Dose to a member of the public to be less than 25 mrem in a year. Dose via the air pathway to comply with 40 CFR 61. Reasonable effort to maintain releases of radioactivity to the environment as low as reasonably achievable.***

Based on the analyses in the performance assessment and supplemental material, there is a reasonable expectation that the dose limit of 25 mrem in a year via all pathways will be met. This conclusion is based on the rationale provided in the PA that drinking groundwater dominates the dose to an offsite receptor for the various groundwater exposure scenarios, that a performance target of 4 mrem is used for the drinking water pathway, and that the dose from the air pathway is relatively insignificant.

In conducting the assessment of saltstone, the analysts considered four cases. The cases comprise combinations of an intact or failed upper barrier with an intact or failed vault and saltstone. The upper moisture barrier controls how much of the 124 cm annual precipitation reaches the clay and gravel barrier on top of the vaults. If the upper barrier is functioning as designed, infiltration is controlled to 2 cm/yr (see later discussion of barrier performance using different hydraulic conductivity). In the failed barrier cases, infiltration is assumed to be 40 cm/yr, the same as the ambient soil.

For the cases analyzed in which the vault and saltstone are intact, the hydraulic conductivity of the materials has an overriding impact on flow to the groundwater. Hydraulic conductivities of 10^{-10} and 10^{-11}, supported by laboratory studies, are used for the vault concrete and saltstone, respectively. The analysis considered physical and chemical degradation of the vaults and concrete. Physical degradation in the form of crack development is recognized as a possibility. A number of recognized chemical degradation processes were analyzed to determine potential impacts to the integrity of the concrete. Analyses indicate that sulfate attack of the concrete is not significant over the first 10,000 years. Carbonation is predicted to penetrate about 6 inches over the first 10,000 years, but will have a minimal impact on reinforcement steel corrosion. Calcium hydroxide leaching is conservatively estimated to have effects starting beyond 5000 years. And reinforcement steel corrosion (oxidation) is projected to start at about 500 years, but is not expected to be significant until beyond 2000 years. Therefore, over the 1000 year time of compliance, it appears that there would be minor impacts to the integrity of the concrete. It is further expected that the impacts would be in the form of crack development as opposed to disintegration and crumbling of the concrete.

The PA analysts acknowledge the difficulty they had developing a realistic model for the degradation of concrete, so they made simplifying assumptions for the purpose of analyzing degraded concrete and saltstone cases. The assumptions are that cracks exist at the time of closure, they fully penetrate the vault and saltstone, they are spaced 3 m apart and have a width of 0.005 cm. It is further assumed that the cracks do not heal as a result of filling with soil or through precipitation reactions associated with carbonation.

In the four cases analyzed in the PA, it was assumed that the clay and gravel barrier sitting on top of the vaults remained intact with a hydraulic conductivity of 7.6 x 10^{-9}. This barrier is relevant only for the cases involving degraded concrete and saltstone.

In the letter J.R. Cook and JR. Fowler to W.E. Kennedy, Jr., "Summary of Information Developed for the Saltstone RPA (U)," SRT-WED-93-203, July 8, 1993, site personnel presented and interpreted additional calculations which evaluated among other things, higher hydraulic conductivities for the vault and saltstone, and for the gravel and clay barriers. The revised analyses use a hydraulic conductivity for the clay of 10^{-7} which is more representative of that achievable in field applications. This results in an increase from 2 cm to 4 cm in the amount of precipitation that infiltrates the fully functioning upper barrier. The more important impact of this higher hydraulic conductivity is that it increases the amount of water penetrating the lower gravel and clay barrier and entering the degraded concrete through the cracks.

The PA lists 47 pathways that could lead to exposure of an offsite receptor. The predominant means of moving nuclides from saltstone to the environment is through leaching and groundwater transport. Therefore, those pathways that are associated with groundwater are expected to be the most important. These include drinking contaminated groundwater, consuming vegetables watered with contaminated groundwater, ingestion of small amounts of contaminated soil on the vegetables, consuming meat and milk from animals that drink contaminated groundwater, direct exposure to soil containing radionuclides from watering with contaminated groundwater, and inhalation of soil that has been contaminated with groundwater. The other pathways are considered to be insignificant because they are easily bounded by conservative analyses (e.g., exposure via the air pathway is analyzed for an intruder residing directly above saltstone), are recognized as having a minimal impact on dose compared to other pathways, or result in significant dilution so as to be inconsequential (e.g., transport to surface waters).

The PA further evaluates the pathways contributing to the all pathways dose in terms of the drinking groundwater pathway alone. The conclusion of this evaluation is that the combination of the higher performance objective for all-pathways (25 mrem/yr versus 4 mrem/yr for drinking water) and the losses resulting from transferring from one medium to another allows one to conclude that the all-pathways performance objective will be met if the 4 mrem/yr drinking water performance target is met. This conclusions is based on the air pathway being inconsequential as is discussed below. To support this assertion, the PA presents comparisons of the expected dose from drinking water versus the dose from other pathways for four radionuclides (Tc-99, Sn-126, Cs-137 and Pu-239). The four radionuclides represent a range of distribution coefficients (Kd's of 1.5 to 4500 ml/g) and a range of plant to soil concentration ratios (0.02 to 2.4). Based on the assumptions and parameters used, the dose from groundwater would exceed the dose from the other pathways by a factor of two for Tc-99, by 0.7 for Sn-126, by a factor of two for Cs-137, and by a factor of seven for Pu-239. The fact that the performance objective for the all-pathways dose is a factor of six higher than the drinking water performance target leads to the acceptability of the conclusion. Therefore, compliance with the all-pathways performance objective is assumed based on meeting the drinking water performance target.

In order to have a manageable suite of radionuclides for which detailed analyses are performed, the PA analysts conducted screening analyses. The first screen was to eliminate radionuclides with a half-life of less than five years from further consideration. Recognizing that the radionuclide concentrations in saltstone will meet the Nuclear Regulatory Commission Class A limits, the 20 half-lives that would occur during the 100 year active institutional control period assumed for intruder analyses would result in insignificant levels of these radionuclides remaining. The second screen is extremely conservative in that it compares the radionuclide concentration in the saltstone pore fluid with the drinking water concentration that would result in a dose of 4 mrem/yr. Radionuclides were selected for further analysis if the pore fluid concentration exceeded the drinking water concentration limit that corresponds with a dose of 4 mrem/yr. The following ten radionuclides were included in the detailed analyses as a result of the screening process: H-3, C-14, Se-79, Sr-90, Tc-99, Sn-126, I-129, Cs-137, Pu-238, and Am-241.

Analyses of the four cases originally included in the PA showed that four of these radionuclides dominate the doses via the drinking water pathway. For the intact vault cases, only Se-79 and I-129 are significant. For the degraded vault cases, the same two radionuclides and Tc-99 and Sn-126 are significant. The other nuclides account for peak doses of less than 10^{-8} mrem/yr.

Sensitivity and uncertainty analyses were performed on various processes and related parameters to determine how significant they were to facility performance. The following processes and associated parameters were analyzed:

- distribution coefficient (Kd) in the saltstone which controls both the pore fluid concentration for a constituent as well as how rapidly it leaches from the saltstone;

- fluxes to the water table from intact vaults as affected by

  - concrete hydraulic conductivity;
  - concrete diffusivity;
  - concrete porosity;
  - saltstone hydraulic conductivity;
  - saltstone diffusivity;
  - backfill hydraulic conductivity;
  - soil capillary pressure;
  - vault infiltration rate; and
  - vault roof geometry.

- increased hydraulic conductivity of the vault and saltstone.

- fractional (portion of the entire inventory) release rate for degraded vaults as affected by

  - depth of perched water;
  - crack width;
  - crack spacing; and
  - distribution coefficient.

- clay and gravel barrier hydraulic conductivity.

- groundwater flow and transport as affected by
  - recharge;
  - vertical and horizontal hydraulic conductivity of the three geologic layers underlying the Saltstone Disposal Facility.

An analysis of doses from the 10 key radionuclides was conducted using the most conservative (lowest) distribution coefficient expected for the constituents in intact saltstone. This maximizes the concentration of the constituent in the pore fluid. Even though there would be some retardation for all constituents except those with a zero distribution coefficient this analysis did not account for it. The analysis found that, with the exception of Cs-137, the peak concentration of all of the radionuclides in the groundwater was less than necessary to cause a dose of 4 mrem/yr. The Cs-137 concentration exceeded the limiting concentration by 10%. There are two large mitigating factors related to this. The distribution coefficient analyzed in this sensitivity analysis for Cs-137 is 1; the travel time to the water table for a constituent with a zero distribution coefficient (i.e., no holdup) is 7500 years, well beyond the period of compliance. Secondly, no credit was taken for the radioactive decay that would occur prior to reaching the water table.

In evaluating the sensitivity to those factors listed above under the heading of flux to the water table, it was found that the results were most sensitive to the conductivity and diffusivity of concrete and saltstone. A statistical analysis using a method called Latin Hypercube Sampling was used to test the combined impacts of these four parameters. In this method the computer samples the range of values for each parameter based on the defined distribution and performs the analysis with the sampled values. In this case 100 runs were made with the maximum peak flux being about 50 times higher and the minimum peak flux being about 1.25 time lower than the reference result. The reference result was based on an analysis that predated the cases used in the PA and therefore did not include the gravel and clay layer sitting on top of the vaults. The conclusions of the analyses would not be different because of this difference. It is noted that decreasing the saltstone hydraulic conductivity by two orders of magnitude only reduces the flux by 30%. This occurs because the transport is dominated by diffusion rather than advection at lower hydraulic conductivities. As in the above case, peak flux to the groundwater occurs well beyond the 1000 year time of compliance because the analysis was done using a constituent with a Kd of zero. Short- to medium-lived radionuclides would decay prior to reaching the groundwater, further reducing the peak flux.

Analyses of the impacts of increased hydraulic conductivity in the vaults and saltstone was performed separate from the above-discussed analysis for the four radionuclides significant to the groundwater pathway analysis (Se-79, Tc-99, Sn-126, and I-129). In one simulation an increase in the hydraulic conductivities by 2 and 3 orders of magnitude for the vault concrete and saltstone, respectively, were used. In a second simulation, in addition to increasing the hydraulic conductivity, the effective diffusion coefficient was increased by two orders of magnitude. The results show a significant increase in dose, in response to the increased conductivity, however, the resulting doses were on the order of 0.1 mrem/yr, significantly less than the 4 mrem/yr target.

The sensitivity/uncertainty analyses for the degraded vaults evaluated the impacts of the depth of perched water sitting on the vaults, the spacing between cracks, the width of cracks and the distribution coefficient. The analysts argue that the semi-analytical approach used for modeling the cracks provides a significant degree of conservatism, but that the uncertainties associated with the model and scenario are not amenable to quantification. The analysis shows that the results are relatively insensitive to the crack width, and most sensitive to depth of perched water, crack spacing and the distribution coefficient. There appears to be a linear relationship between release fraction and the depth of perched water and the crack spacing.

In association with the supplemental analysis in which the analysts revised the hydraulic conductivity used for the gravel and clay layer, an additional sensitivity/uncertainty analysis was performed. The additional analysis assigned a hydraulic conductivity to the gravel and clay layer equal to that of the native soil (10^{-5} cm/s) which is two orders of magnitude less than that used in the supplemental analysis. Doses from four of the ten key radionuclides were calculated using this greater hydraulic conductivity. The resulting doses were 200 to 300 times higher than those calculated for a hydraulic conductivity of 10^{-7}. These results mean that the peak doses from drinking water would be 30 mrem/yr (Tc-99), 40 mrem/yr (I-129), and 80 mrem/yr (Se-79) compared to the dose limit of 4 mrem/yr. Note however that these peak doses occur beyond the 1000 year time of compliance (from 2400 to 15,000 yr). Doses at the time of compliance are not available from the information presented. These results are partially a function of the assumption that all of the water flows through the cracks in the analysis of a degraded vault. The doses projected by these simulations are recognized as being unrealistically high because the lower gravel and clay barrier would be minimally susceptible to degradation from drying, erosion, and biointrusion due to the protection provided by the overlying sediments. However, the analyses do point out the importance of this gravel and clay layer to controlling doses to acceptable levels and the need to conduct confirmatory studies.

Sensitivity/uncertainty analyses of groundwater flow and transport were performed using a constituent with a distribution coefficient of zero. Recharge was evaluated at rates of 2 cm/yr (11 times the recharge used in the four base cases) and 40 cm/yr. There was a small affect on water table level from the 2 cm/yr recharge and essentially no significant effect on the peak concentration. At the 40 cm/yr recharge, there was a modest affect on the water table and a reduction in peak concentration of about 48%. This indicates that the recharge in the range expected through the Saltstone Disposal Facility (a few centimeters or less) has much less effect on flow than recharge from around the facility.

The hydraulic conductivities in three dimensions were tested for the three hydrologic units underlying the Saltstone Disposal Facility using the Latin Hypercube Sampling method. The results show that the flow regime is most sensitive to the vertical component of the middle unit (an aquatard) and the horizontal components of the upper unit. This analysis focused on the nonradioactive component, nitrate, and was not useful in this compliance evaluation except for demonstrating that the analysts had a reasonable understanding of the limitations of the PORFLOW model for their groundwater flow regime.

There is also a reasonable expectation that the doses to an offsite member of the public via the air pathway will be far below the limits of 40 CFR 61, that is, 10 mrem/yr exclusive of doses from radon. For the air pathway, performance is evaluated against 10 mrem/yr for H-3 and C-14, two radionuclides which can become available through vapor diffusion to the ground surface. Section 4.3 of this evaluation addresses the dose to a hypothetical intruder who lives 24 hours a day, 365 days a year in a basement 15 cm above the saltstone. The estimated doses from this bounding analysis are 10 mrem/yr from H-3 and 4 x 10^{-7} mrem/yr from C-14. This analysis is adequate to provide a reasonable expectation that the 10 mrem/yr dose limit to an offsite receptor will be met due to the extreme conservatism of the analysis in Section 4.3, the attenuation that would occur between the saltstone and the ground surface, and dispersion that would occur between the vaults and the 100 m point of compliance.

The performance of radon in the disposal system was evaluated against a flux rate of 20 pCi/m^2/s. This is not a limit explicitly called out for LLW management in Order DOE 5820.2A or in 40 CFR 61. It is the limit used in the uranium mill tailings program and is generally accepted as a surrogate limit for LLW disposal facilities. Appendix A of the PA presents a conservative estimate of the flux rate from saltstone. Some of the conservatisms used include calculating the flux at the surface of the saltstone (i.e., taking no credit for attenuation through the overlying barriers); an assumption that U-234 is in secular equilibrium with Ra-226 which will not occur until well after the 1000 year time of compliance; not accounting for depletion of the source inventory through leaching; and use of an effective diffusion coefficient for dry material when the saltstone is expected to be 80-90% saturated. The resulting flux rate is estimated to be 0.1 pCi/m^2/s.

The following table summarizes the results of the performance analysis for the performance measures listed. For the all-pathways and drinking water measures, the reported results correspond to the cases in which the upper moisture barrier has failed. It is noted that the reported results are maxima that occur beyond the 1000 year time of compliance. Therefore, compliance with the performance objective during the 1000 years time of compliance is readily projected.

Performance Measure (1)	Results Intact Vaults	Results Degraded Vaults
All-pathways (25 mrem in a year)	<25 mrem/yr (2)	<25 mrem/yr (2)
Drinking water (4 mrem in a year)	0.001mrem/yr	0.6 mrem/yr
Air pathway (10 mrem in a year)	<<10 mrem/yr (3)	<<10 mrem/yr (3)

Radon emission (20 pCi/m²/s)	0.1 pCi/m²/s (4)	0.1 pCi/m²/s (4)

1 The first and third performance measures are performance objectives directly from Order DOE 5820.2A. The second performance measure was imposed by the site to evaluate compliance with State groundwater limits. The fourth performance measure is used in this review for radon emission.

2 Results of analyses relative to the all pathways dose limit are inferred based on the calculated drinking water dose and the relative significance of other pathways.

3 A conservative, bounding analysis of the dose to an intruder residing 15 cm above saltstone resulted in a maximum dose of 10 mrem/yr. Dose to an offsite receptor would be orders of magnitude less.

4 A single analysis for radon flux at the surface of saltstone was performed. The condition of the saltstone is inconsequential to the analysis.

An ALARA analysis has not been discussed in the PA. Earlier work on saltstone formulation which constitutes part of an ALARA analysis has already been performed and PA results imply that extension of the analysis would have minor effects. It is necessary for the site to document and report the conclusion of a more complete analysis.

4.3 *Dose to intruder to be less than 100 mrem in a year for chronic exposure. Dose to intruder to be less than 500 mrem in a year for an acute exposure.*

Based on the analyses in the performance assessment and supplemental material, there is a reasonable expectation that the dose limits of 100 mrem in a year from chronic exposure of a hypothetical intruder and 500 mrem/yr from an acute exposure of an intruder will not be exceeded.

The PA included consideration of a number of chronic and acute intruder exposure scenarios. The scenarios that would result in chronic exposure of intruders are an excavation-agricultural scenario, a drilling-agricultural scenario, and an excavation-resident scenario. Scenarios resulting in acute exposure of a hypothetical intruder were excavation, discovery, and drilling. The PA concludes that showing compliance with the chronic exposure performance objective will assure that the acute exposure performance objective will be met. This is based on a consideration of the acute exposure scenarios in relation to the chronic exposure scenarios, intruder analysis literature, and the higher dose limit for acute exposure (500 mrem versus 100 mrem/yr for chronic exposure). Therefore, in this compliance evaluation demonstrating compliance with the 100 mrem/yr performance objective for chronic exposure will constitute compliance with the 500 mrem/yr acute exposure performance objective.

The PA identified two variations of the excavation-agricultural scenario that it considered. The first is the traditional case whereby excavation for a basement results in bringing waste to the surface. Subsequently, this waste material, which is assumed to be indistinguishable from soil is mixed with garden soil. Chronic exposures result from direct exposure in the house and the garden, consumption of contaminated vegetables, ingestion of contaminated soil on the vegetables, and inhalation of contaminated dust while working in the garden. Due to the characteristics of the Saltstone Disposal Facility and the time that would be required for the vaults and saltstone to lose sufficient structural integrity so as to be excavated, this compliance evaluation considers this scenario to not be credible during the 1000 year time of compliance. The alternate excavation-agricultural scenario involves excavation of, and incorporation into a garden, soil from above an intact vault that becomes slightly contaminated from the upward migration of radionuclides from the vaults. This scenario results in a dose to the hypothetical intruder of 10^{-5} mrem/yr.

A residential scenario is hypothesized in which the intruder excavates until finding the vault or saltstone. The PA argues that in times shortly following the assumed 100 year active institutional control period, the intruder would encounter the vault roof. Therefore, the intruder would benefit from the shielding provided by the clean grout cap on top of the saltstone and the concrete of the vault roof. It is then assumed that the intruder builds a house on the vault and receives a dose of 0.6 mrem/yr from direct exposure. An additional, conservative analysis is included in the PA in which the clean grout and concrete roof have degraded such that they are excavated as soil and the intruder is stopped by direct contact with saltstone. This second scenario requires a time that is well beyond the 1000 years time of compliance for degradation of the concrete and grout so is not considered credible in this compliance evaluation.

Although the second residential scenario is not relevant to the findings of this compliance evaluation it does provide the scenario for considering exposure via inhalation to the volatile radionuclides, H-3 and C-14. Exposure through inhalation is hypothesized for a person living year-round in a basement room 15 cm above saltstone. This bounding analysis results in a dose of 10 mrem/yr, well below the performance objective of 100 mrem/yr.

As with the excavation-agricultural scenario, two variations of the drilling-agricultural scenario were considered in the PA. And as with the excavation-agricultural scenario, the variation that assumes intrusion directly into the waste is not considered in this compliance evaluation because it is not credible during the 1000 year time of compliance. The alternative drilling scenario assumes that contaminated soil is brought to the surface in the process of drilling a well adjacent to a vault. The soil is assumed to have been contaminated by lateral migration from the vault. The exposure pathways are the same as discussed above for the other agricultural scenario and the resulting dose is 10^{-4} mrem/yr.

Since DOE will control the land where the Saltstone Disposal Facility is located, an inadvertent intruder is an unlikely event that would occur for only a short period of time. The scenarios and parameters selected are considered adequate for concluding that there is a reasonable expectation of meeting the performance objectives. The PA presents additional analyses of intrusion at times well beyond 1000 years. However, these analyses were not needed in making a determination of compliance. These additional analyses show that ultraconservative scenarios involving complete degradation of the concrete and saltstone result in calculated doses of 16 to 76 mrem/yr (letter, J.R. Cook and J.R. Fowler to W.E. Kennedy, Jr., July 8, 1993).

The maximum annual dose to a hypothetical intruder relative to the performance objectives are shown below:

Performance Objective	Estimated dose
100 mrem/yr chronic exposure	0.6 mrem/yr
500 mrem/yr acute exposure	less than the chronic exposure (see p 3-2)

4.4 *Protect groundwater.*

(Insufficient information to complete the evaluation)

Confirmed:______________________________

Date:__________________________________

Attachment 2

Draft conditions that must be met to conditionally accept the performance assessment in all areas excluding groundwater protection are:

1. The Savannah River Operations Office (SR) is to submit a composite analysis which includes the Saltstone Disposal Facility by September 30, 1997, as committed to in the DNFSB Recommendation 94-2 Implementation Plan, Revision 1.

2. The site is to address the requirement for an ALARA analysis in accordance with the latter part of DOE Order 5820.2A, Chapter III, 3.a.(2). The detail of this analysis should be commensurate with the calculated doses.

3. An addendum to the performance assessment, or a revised performance assessment, is to be issued by January 31, 1997. The addendum is to include the additional information developed by the site in response to number 2 above and the supplemental information provided subsequent to submittal of the performance assessment (e.g., in response to requests from the PRP). The addendum or revision must be distributed to all known holders of the performance assessment. The purpose of this condition is to ensure that the documentation that was the basis for HQs' acceptance is readily available to any party interested in the performance assessment.

4. By July 31, 1997, the site is to develop a plan that commits to schedule and budget for conducting studies to address the uncertainties surrounding the critical factors affecting performance of a degraded system. For example, the plan could address closure studies that support the hydraulic conductivity of the cover over the vault, improved modeling of the degraded vault, or both.

5. Any contemplated changes in the design of the Saltstone Disposal Facility that were not analyzed in this performance assessment are to be analyzed, and the analysis submitted to and accepted by Headquarters prior to construction. This is consistent with the philosophy in the July 21, 1995 memorandum, "Interim Policy on Regulatory Structure for Low-Level Radioactive Waste Management and Disposal" as it applies to maintenance of performance assessments and to constructing new facilities.

6. The site is responsible for maintaining this performance assessment in accordance with the memorandum, "Interim Policy on Regulatory Structure for Low-Level Radioactive Waste Management and Disposal" (July 21, 1995). This includes the acquisition of field data needed to improve confidence in the analyses and reduce critical uncertainties. Headquarters will issue guidance for implementing this requirement in September 1996.