CONF-941214--4

ENERGY DIVISION

# PERFORMANCE ASSESSMENT EXPERIENCE AT OAK RIDGE NATIONAL LABORATORY

D. W. Lee
Oak Ridge National Laboratory
Oak Ridge, TN 37831-6206

To be published in
the 16th Annual U.S. Department of
Energy Low-Level Radioactive Waste Management
Conference Proceedings, December 13-15, 1994

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-840R21400



MASTER



DLC

## DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

# PERFORMANCE ASSESSMENT EXPERIENCE AT OAK RIDGE NATIONAL LABORATORY

D. W. Lee
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, TN 37831-6185
(615) 574-5803

## ABSTRACT

The development of a performance assessment (PA) for low-level radioactive waste disposal operations at Oak Ridge National Laboratory (ORNL) was initiated in 1989 and is continuing. A draft PA was prepared in September 1990 and submitted to the DOE Peer Review Panel for review and comment. Recommendations were received that formed the basis for a revised PA that was completed in December 1993. The review of the revised PA is continuing. This paper reviews the experience gained in the preparation of the PA including the technical difficulties associated with performance assessment in Oak Ridge and an overview of the methods used in the PA. Changes in waste operations that resulted from the findings in the PA include improved waste acceptance criteria, waste certification, and waste management practices. The discussion includes issues that relate to the application of current performance objectives to older disposal facilities, which are being addressed as part of the CERCLA process.

## BACKGROUND

DOE Order 5820.2A was issued on September 26, 1988[1] and included the requirement that a site-specific radiological performance assessment (PA) for the disposal of waste be prepared and maintained for the purpose of demonstrating compliance with performance objectives contained in the Order. The contents of such an assessment were not defined by the Order other than to include site-specific geohydrology and waste composition; however, the PA was to support the methods used for waste disposal and the engineered modifications for the disposal site. The PA was to be reviewed by an Oversight and Peer Review Panel that had the charge of ensuring consistency and technical quality around the DOE complex. Support for preparing the PA was to be derived from existing resources.

In the following six months an implementation plan for Oak Ridge National Laboratory (ORNL) was prepared, pursuant to the Order, describing schedules, costs, and quality assurance activities for compliance with the Order and including the preparation of PAs for ongoing disposal operations at Solid Waste Storage Area 6 (SWSA 6), and new disposal facilities at SWSA 7 and West Bear

Creek Valley[2]. The PA for ongoing disposal operations was scheduled to be completed in FY 1991, and the PA for new disposal operations was scheduled to be completed in FY 1994. The total cost for preparing PAs for both present and future facilities was estimated to be $500K.

On February 28, 1989, T. B. Hindman, Director, Office of Defense Waste and Transportation Management, Defense Programs, issued "Clarification of Requirements of DOE Order 5820.2A" which included guidance on the PA requirement. In April 1989, the Oversight and Peer Review Panel issued a format and content guide for PAs[3] that endorsed the guidance document prepared prior to issuance of the Order[4]. These documents served as the foundation for the development of the PA at ORNL. This paper discusses the experience to date at ORNL in complying with the PA requirement of DOE Order 5820.2A.

## THE DRAFT PA

The preparation of a PA for SWSA 6 was initiated at the beginning of FY 1990 with the milestone to complete the preparation of a draft by the end of FY 1990. The scope was to address all disposal operations that had occurred after issuance of the Order and to ignore all disposal operations that had occurred prior to the date of issuance.

SWSA 6 has been used as the disposal facility for low-level radioactive waste at ORNL since 1973. It is a 68 acre tract of land within the Oak Ridge Reservation (ORR) with approximately half of the land unsuitable for disposal of wastes because of steep terrain. Shallow land burial of radioactive waste was the disposal technology prior to 1986 when below-grade greater confinement disposal technologies were implemented. Above-grade tumulus disposal was initiated in April 1988. Some areas of SWSA 6 were remediated under a RCRA interim status closure agreement. The site will be closed under CERCLA. The overlap of RCRA/CERCLA actions with disposal operations after September 26, 1988 was and still is an issue with respect to compliance with the performance objectives of the Order, because the actions to be taken under CERCLA will define how the site will be closed. The CERCLA process has not yet been completed, so the closure design for SWSA 6 is not known with certainty.

The complex geohydrology and the varied technologies used for the disposal of wastes in SWSA 6 complicate the preparation of a performance assessment. SWSA 6 includes two geologic formations with a varying dip of about 10-15°. Strike also varies across the site with numerous folds and localized faulting. The soils are primarily residual products derived from weathering and leaching of the underlying bedrock with soil masses thickest beneath upland terrain and thinnest at ephemeral creeks within the site. With 53 inches of annual precipitation, the shallow soils quickly transport up to 90% of the precipitation to ephemeral creeks within the uppermost 100 inches of soil. Below-grade disposal units that intercept this geohydrologic feature collect substantial quantities of water and increase locally the recharge to the uppermost water table aquifer. Disposal technologies that have been used in SWSA 6 include below-grade silos, wells, biological trenches, and above-grade tumulus vaults. Preparing a site-specific PA that captures the effects of the many different disposal technologies and the complex site characteristics was a daunting challenge.

Environmental data collection and modeling studies have been conducted for many years at SWSA 6. However, site-wide data with a significant record length and site-wide modeling investigations were limited. Models that could address the site-specific performance of concrete in below-grade and above-grade disposal units over extended periods of time were not available. Lacking available models for describing the site and disposal technologies, the initial activities towards preparing a PA were directed towards model development for water transport at SWSA 6. The approach was to identify models that would apply to analyzing the generation of the source term, the behavior of the shallow subsurface and the groundwater, and to link these models in series. This concept of a serial chain of models was quickly modified to allow for the separate models to be interactive in order to address the exchange of water between the shallow subsurface and the different disposal technologies. The models selected for application to the PA were NEWBOX[5] and FLOWTHRU[5] for the source term, UTM[5] for the shallow subsurface, and USGS-MOC for groundwater.

NEWBOX is a simple diffusion model of leachate generation in contaminated concrete. It was combined with FLOWTHRU which calculated the diffusion of contamination through uncontaminated concrete to produce a source term. UTM is an elaborate water budget model for landscapes with varied terrain and vegetation that has been verified and tested on the ORR. The USGS-MOC model is

a classical groundwater model that was used with success in a model validation study in neighboring Bear Creek Valley, which has the same geology as SWSA 6. As the model development proceeded, a scoping study was prepared that identified the critical pathways to be investigated in the PA[5]. The scoping study identified the critical isotopes to be considered in the PA from the long list of radionuclides in waste, and justified focusing he analysis on the transport of contamination by groundwater and surface waters.

The linkage of these models was complicated by the time step for each model. By necessity, UTM used a time step of one hour to represent the storm related behavior associated with shallow subsurface phenomena. NEWBOX and FLOWTHRU required inputs of monthly infiltration and shallow subsurface inflow. USGS-MOC used annual recharge values and leachate fluxes. Discharges of contamination to surface waters from shallow subsurface flows and groundwater were calculated on an annual basis. Passage of data from one model to the next with proper time sequencing was developed as a separate modeling component.

The complex terrain and geohydrology of SWSA 6 required substantial assumptions and tuning in order to replicate the major features of the site. The structured geologic medium was represented as an equivalent porous medium while the shallow subsurface phenomena were modeled using empirical relations developed from previous studies that accounted for the complex terrain. While the resulting models are simplifications of the actual site conditions, the results were consistent with the available site data.

The linked models were used to estimate the dose consequences from waste disposal over the projected inventories for the site. Projected inventories were derived from the records of disposals that occurred between September 1988 and August 1989. They were linearly extrapolated to the planned loading for the disposal units at SWSA 6. The highly variable nature of waste disposals at ORNL introduced substantial uncertainty into these projected inventories.

Doses were determined using well established exposure scenarios and exposure pathways analysis methods. Central to the calculations was the understanding that contaminated groundwater in SWSA 6 discharges to ephemeral creeks within SWSA 6. This observation is consistent with all available monitoring data that indicate that no groundwaters from within SWSA 6 migrate outside the facility.

Inadvertent intrusion by an intruder-agriculture scenario was evaluated at 300 years after closure due to the integrity of the concrete monoliths associated with each disposal unit type. The intruder-resident and intruder-drilling scenarios were assumed to occur 100 years after closure. Doses for 35 isotopes were determined for the exposure scenarios associated with the consumption of contaminated water and direct intrusion. The maximum doses attributed to each isotope and the time at which the exposure occurred were determined.

The results of the draft PA indicated that SWSA 6 was not in compliance with all of the performance objectives of DOE Order 5820.2A. Although compliance with the performance objective protecting groundwater was demonstrated, the interpretation of results suggested that the results may not be conservative, because no account was taken for the degradation of concrete or advective releases of contamination. The performance objectives for protection of the inadvertent intruder were exceeded for all disposal units except the biological trenches. Compliance with the off-site performance objective was demonstrated, but the potential for underestimating potential doses was noted in the interpretation of results. Recommendations for improving the draft PA analysis and developing waste acceptance criteria (WAC) based on the draft PA were formulated. The draft PA was completed in September 1990[6] at a cost of $500K.

## REVIEW OF DRAFT PA

The draft PA was submitted to DOE-ORO for review and concurrence in September 1990. Subsequently, the PA was transmitted to DOE-HQ and the DOE Peer Review Panel. The Peer Review Panel conducted a review in March 1990 based on the draft PA, a visit to SWSA 6, presentations by the PA preparers, and presentations by ORNL waste operations. As part of the presentations, the plan for bringing SWSA 6 into compliance with the performance objectives of DOE Order 5820.2A was provided, including the development of improved WAC, waste segregation, and waste certification. Extensive recommendations were provided by the DOE Peer Review Panel for development of a revised PA by ORNL.

The Peer Review Panel recommendations included the extension of the analysis to the peak dose for each radionuclide, the critical examination of the inventory of radionuclides, the analysis of the degradation of concrete barriers and the effect of advective transport, the verification of NEWBOX and FLOWTHRU, and

improvements in the uncertainty analysis. Several recommendations were associated with the integration of RCRA/CERCLA activities with the PA. These latter recommendations were addressed to the extent possible, but their incorporation into the PA was limited by the legal and regulatory requirements of the RCRA/CERCLA process.

Waste operations were modified in response to the review of the draft PA and updated WAC were developed. Plans were formulated to discontinue operations in disposal units that posed an excessive risk to an inadvertent intruder and implementation of these plans was initiated within the constraints of the available resources. Plans were also prepared for revising the PA in response the recommendations of the DOE Peer Review Panel. Interaction with the State of Tennessee concerning the results of the draft PA were also initiated.

## REVISED PA

Revision of the PA was initiated in 2Q FY 1992. The delay was a result of inadequate resources to initiate the revision. The initial efforts in revising the PA were in the critical evaluation of the inventory, the development of an improved uncertainty analysis, and the development of an improved source term model considering concrete degradation and advective transport of contamination. Resolution of these issues extended through the end of FY 1992. At the beginning of FY 1993, the revision of the PA was formally initiated. All of the areas identified in the DOE Peer Review Panel comments and in the future work identified in the draft PA were incorporated into the revised PA.

A new source term model was developed by Rogers and Associates that incorporated the release mechanisms not addressed in the draft PA[7]. The new models accounted for the degradation of concrete until the strength of the structure was inadequate to support the load, at which point hydraulic failure of the disposal unit occurred. Separate codes were developed for the above-grade and below-grade disposal units. A separate program was developed to account for the differing releases from the above-grade and below-grade disposal units. Verification of the codes was initiated as the revised PA was being prepared.

The existing inventory of wastes disposed of in SWSA 6 was critically examined by a detailed review of every waste manifest since September 26, 1988.

Additionally, an analysis of the characterization techniques used by waste generators was performed and quantitative estimates of the ranges in concentration for each isotope were made based on the characterization methods used. This latter analysis revealed orders of magnitude variations in radionuclide inventories with the characterization techniques used for some isotopes. Additional isotopes that had not been considered in the draft PA were identified during this analysis and were added to the inventory for the revised PA.

The uncertainty analysis was improved by the introduction of Latin Hypercube sampling of critical parameters in the models used in the performance assessment. The sampling was performed about the maximum concentration estimated by the models using distributions derived from data or best estimates. The models were further interrogated by using Bayesian methods to consider the subjective conditional probability that the models were representative of the actual system. The improved analysis was invaluable in the interpretation of results[8].

Dose analyses consistent with the methodology used in the draft PA were prepared for the revised PA. The results indicated that the ongoing operations at the SWSA 6 Interim Waste Management Facility (IWMF) exceeded the performance objective for protection of groundwater, though all other disposal units met the groundwater protection performance objective. The off-site performance objective was shown to be satisfied for SWSA 6. The results of the revised PA indicated that the biological trenches, asbestos silos, fissile wells, and Tumulus II met the performance objectives for inadvertent intrusion. However, if compliance with the performance objectives was extended to beyond one million years, only the biological trenches were shown to be in compliance. The exceedance of the performance objectives at distant times is the consequence of uranium daughter buildup and subsequent exposures to radon and radium.

The exceedance of the groundwater protection performance objective was associated with a small area adjacent to the IWMF and the isotopes $^{14}C$, $^{36}Cl$, $^{239}Pu$. Significant uncertainty in the actual inventory is associated with $^{14}C$ as a result of the characterization methods used by the generators. The doses attributable to $^{36}Cl$ and $^{239}Pu$ were the consequence of one-time disposals.

Future work toward improving the PA and changes in operations were also included in the PA. The revised PA used the best estimate of the closure design for SWSA 6 under the CERCLA process. Alternative designs for the CERCLA closure of SWSA 6 could dramatically affect the results presented in the PA. Further improvements were needed in the verification of the source term models, along with improvements in the WAC and waste certification methods. Changes in waste operations were also incorporated into the PA. All below-grade disposal operations were terminated as of January 1, 1994. Commitments were made to remove from the IWMF, the one-time disposals of $^{36}Cl$ and $^{239}Pu$. The revised PA was completed in December 1993[9] with a total cost of the draft and revised PA of $1.5M. The revised PA was submitted to DOE-ORO for review and concurrence in December 1993.

## REVIEW OF REVISED PA

The revised PA was submitted to DOE-HQ in March 1994 and subsequently to the DOE Peer Review Panel for review. The DOE Peer Review Panel conducted a completeness review of the SWSA 6 PA in May 1994. Several items were identified as additional information requested prior to completing the review. These requests for information are currently being addressed. Once completed and submitted to the DOE Peer Review Panel, the review of the revised PA will continue. If the revised PA is considered to be technically acceptable and consistent with other PAs across the DOE complex, it will be forwarded to DOE-HQ for approval.

## DISCUSSION

The issuance of DOE Order 5820.2A included the requirement for a PA that was addressed by ORNL for SWSA 6. SWSA 6 was not designed or operated prior to September 26, 1988 with the intent of complying with rigorous performance objectives, such as those contained in the Order. PA activities over the past six years have identified areas of concern that warrant consideration. Responses to the findings of the PA have reduced the potential for future groundwater contamination, resulted in changes to the WAC and waste certification program, and increased the overall understanding of the performance of SWSA 6.

Initially, the PA requirement was considered to be a compliance document that was to be prepared as a draft and revised to be a final document. Over the course of the development of the SWSA 6 PA, the need for the PA to be revised periodically as changes are made has become more apparent. In the case of SWSA 6, future revisions will be needed to ultimately demonstrate compliance with the performance objectives of DOE Order 5820.2A. Unlike a new facility where a design can be evaluated prior to the initiation of disposal operations, SWSA 6 disposal operations are being improved incrementally as more knowledge is gained, so the facility will be closed in compliance with the existing DOE Order. Consequently, the PA has evolved from a compliance document to a living document that will be revised throughout the operation and closure of SWSA 6.

The costs and schedule for completing the PA process have been substantially greater than originally anticipated. The increased costs and time commitments, as compared to the initial estimates, have been the result of the difficulty in conducting a site-specific assessment and addressing all of the factors that contribute to the overall evaluation of waste disposal operations at SWSA 6. Without the benefit of the PA process, many of the improvements in waste management operations would not have occurred.

## REFERENCES


1. U. S. Department of Energy, *Radioactive Waste Management*, DOE Order 5820.2A, Chapter III, September 1988.

2. J. S. Baldwin, T. E. Myrick, C. M. Kendrick, L. D. Bates, *Oak Ridge National Laboratory Implementation Plan for DOE Order 5820.2A*, ORNL/TM-11166, April 1989.

3. U. S. Department of Energy, *Recommended Format and Content for DOE Low-Level Waste Disposal Facility Radiological Performance Assessment Reports*, DOE/LLW-81, April 1989.

4. U. S. Department of Energy, *Guidelines for Radiological Performance Assessment of DOE Low-Level Radioactive Waste Disposal Sites*, DOE/LLW-62T, July 1988.

5. D. W. Lee, D.C. Kocher, *Scoping Analysis for the Performance Assessment for SWSA 6*, ORNL/CF-90/67, January 1990.

6. Oak Ridge National Laboratory, *Performance Assessment for Continuing and Future Operations at SWSA 6*, Draft, September 1990.

7. R. Shuman, N. Chau, E. A. Jennrich, *The SOURCE Computer Codes: Models for Evaluating the Long-Term Performance of SWSA 6 Disposal Units, Version 1.0: User's Manual*, RAE-9005/8-1, Rogers and Associates Engineering Corporation, Salt Lake City, UT, April 1992.

8. D. W. Lee, M. W. Yambert, D. C. Kocher, "Uncertainty Analysis for Low-Level Radioactive Waste Disposal Performance Assessment at Oak Ridge National Laboratory," *Proceedings of the International Topical Meeting on Nuclear and Hazardous Waste Management Spectrum '94, August 14-18, 1994*, Vol. 2, pp. 1534-1538, American Nuclear Society, La Grange Park, IL, 1994.

9. Oak Ridge National Laboratory, *Performance Assessment for Continuing and Future Operations at Solid Waste Storage Area 6*, ORNL-6783, December, 1993.