Waste Acceptance and Disposal at the Nevada National Security Site – 14448

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ABSTRACT

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) relies on the Performance Assessment (PA) and the PA model of the Area 5 Radioactive Waste Management Site (RWMS) at the Nevada National Security Site (NNSS) to make disposal decisions on waste stream profiles submitted by waste generators. Disposal decisions are made following a formal process called the PA review process. This paper presents the PA review process, which is a part of the NNSA/NFO's Waste Generator Documentation Approval Process. The review process includes three major steps and employs quantitative tools such as the PA-derived factors and probabilistic inventory and PA models developed in GoldSim. The PA-derived radionuclide action levels for waste characterization and reporting are included in the NNSS Waste Acceptance Criteria. Each year, NNSA/NFO reviews approximately 100 to 150 new or revised waste stream profiles. The PA review group ensures that, with the disposal of approved waste streams, the Area 5 RWMS will remain in compliance with the performance objectives of DOE O 435.1, "Radioactive Waste Management." Examples of the PA review process are given that demonstrate how waste streams with special characteristics are evaluated and disposal decisions are made. The most rigorous profile evaluation is done with the PA model, run with the proposed profile inventory added and results compared to the PA results. Additional analysis and process-modeling are performed for those waste streams with unique features not addressed with the PA model. The results of these analyses and modeling are documented in special analysis reports, reviewed and approved by NNSA/NFO. The examples include (1) profiles with radionuclides not in the PA, (2) profiles including radionuclides with high radon-generation potential, and (3) profiles with high-heat generating radionuclides.

INTRODUCTION

The U.S. Department of Energy (DOE), National Nuclear Security Administration Nevada Field Office (NNSA/NFO) directs the management and operation of the Nevada National Security Site (NNSS), which is located in south-central Nevada (Figure 1), about 105 kilometers northwest of Las Vegas, Nevada. The NNSS is approximately 3,561 square kilometers.

Low-level waste (LLW) and mixed low-level waste (MLLW) from the DOE, the U.S. Department of Defense, and commercial firms are disposed at two disposal sites at the NNSS: the Area 5 Radioactive Waste Management Site (RWMS) and the Area 3 RWMS. The Area 3 RWMS is currently in inactive status. The Area 5 RWMS is currently active and is planned to be closed in 2027. The disposal cells in the 37-hectare southern portion of the Area 5 RWMS (Figure 2) have been closed with vegetated monolayer closure covers. The current active cells are in the northern half of the RWMS, consisting of about 44 hectares. In addition, approximately 220 hectares of land is available for future disposal cells.

NNSA/NFO and the NNSS management and operating contractor, National Security Technologies, LLC, provide a comprehensive waste acceptance review and oversight function through the Radioactive Waste Acceptance Program (RWAP). RWAP ensures that generators prepare and submit waste profiles for each waste stream to be disposed of at the NNSS following the NNSS Waste Acceptance Criteria (WAC) [1]. The RWAP's review and approval process is formalized in the Waste Generator Documentation Approval Process (WGDAP) document [2]. A key component of the WGDAP is the Performance Assessment (PA) review process.

Fig. 1. Area 5 Radioactive Waste Management Site Location Map

PA REVIEW PROCESS

Waste generators submit approximately 100 to 150 new or revised waste streams for disposal at the NNSS each year. Each waste stream is reviewed by the PA group following the PA review process for its potential to alter or invalidate the site's disposal authorization basis documents (primarily the PA document) and site's PA model. The underlying premise of the review process is that it can effectively address the following four questions:

- Does acceptance of the waste cause a change in radionuclide inventory?

- Does acceptance of the new waste stream require a change in facility design or closure plans, or require operational constraints or conditions?
- Does acceptance of the new waste stream change the likelihood of a feature, event, or process, or change a model parameter value?
- Does acceptance of the waste stream require a change in WAC, the performance assessment, or the disposal authorization statement?

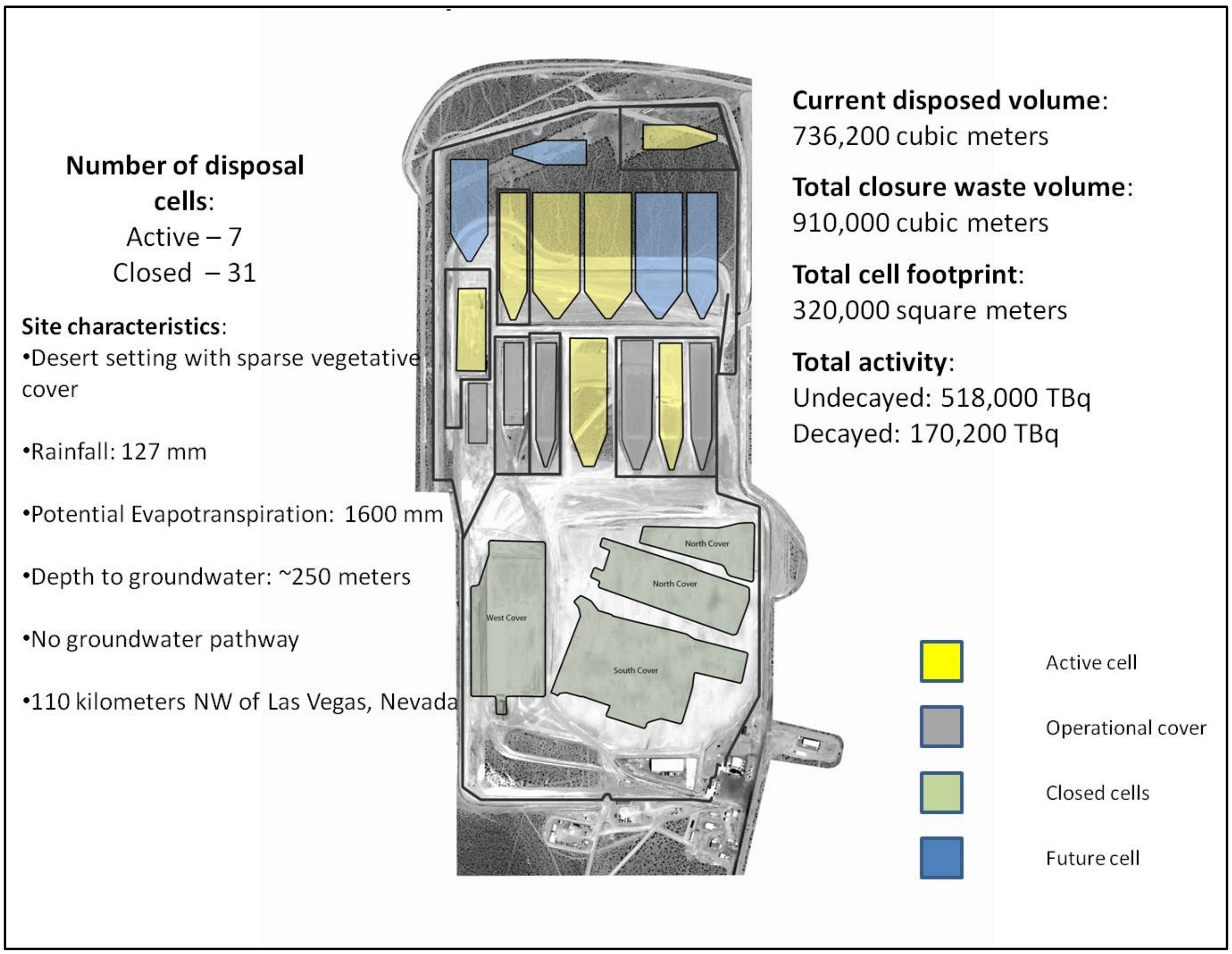

Fig. 2. Characteristics of the Area 5 Radioactive Waste Management Site

Three analytical steps of the PA review process are shown in Table I. Steps 1 and 2 require the least level of effort, and their execution is automated in an Access database. Step 3 requires setting up and running the PA model. Steps 1 and 2 rely on PA-derived factors. The criteria for these steps are presented below, followed by a summary discussion of the inventory and PA models, and the PA-derived factors.

Table I. Key Steps of the Performance Assessment Review Process

Step 1: Categorical Exclusion	If criteria for categorical exclusion are met, the review ends, and it is documented in the database. Otherwise, Step 2 is performed.
Step 2: Inventory Screening	If the inventory screening criterion is met and no other disposal concerns exist, the review ends, and it is documented in the database. If the inventory screening criterion is not met or other disposal concerns exist, Step 3 is performed.
Step 3: Unreviewed Disposal Question Determination	Special analysis is performed for the proposed inventory using the PA model. Additional special analyses are performed for disposal concerns other than inventory.

Categorical Exclusion

Categorical exclusion refers to accepting a waste profile, without further review, when proposed waste volume, radionuclide concentrations, and activity meet the following criteria:

- Concentration sum of fractions of the profile is less than 1.0
- Concentration sum of fractions of the profile is less than 10, and the waste volume is less than 100 m^3
- Profile contains a long-lived nuclide without action level (no waste concentration limit derived) and annual activity less than 3.7e7 Bq (1 mCi)

Inventory Screening

The activity sum of fractions of the proposed profile is calculated. If it is below 0.01, the profile can be accepted without further review. Otherwise, a Step 3 review, which requires a special analysis, is performed.

Special Analysis

Special analysis refers to a documented set of analytical calculations and modeling performed to assess the impact of the proposed waste profile on the PA results. Special analysis is performed for a waste profile that failed to pass the categorical exclusion and inventory screening criteria. A special analysis is also required for waste streams that require changes not limited to radionuclide inventory. Common changes requiring special analysis are waste disposal cell design or disposal of nuclides not in the model. A special analysis is a more thorough and documented analysis, submitted to NNSA/NFO for review.

Inventory and PA Models

The estimate of the Area 5 RWMS closure inventory is prepared using a probabilistic model developed in GoldSim [3]. The model sums past disposals, revisions, and future inventory estimates probabilistically. The model is updated annually with the past year's disposals and revised forecast of future waste volumes. Radioactive decay and ingrowth during the operational period are explicitly included in the model. The closure inventory estimates are well fit by a lognormal distribution and described by a geometric mean and standard deviation for each radionuclide, as input to the probabilistic Area 5 RWMS PA model. The site inventory is divided into three virtual disposal units based on the depth of burial. Most wastes are disposed in shallow land burial disposal units. The inventory of the three virtual disposal units is further divided into pre-1988, post-1988 disposed, and future portions.

The PA model is a probabilistic model also developed in GoldSim. The model includes modules for materials/environmental media properties, radionuclide inventory, disposal cell geometry, source-release, environmental transport, and dose assessments. The model results include doses to a member of the public for various scenarios (all pathways dose and air pathway dose), radon flux, and doses for two intruder scenarios for a compliance period of 1,000 years. The model results are compared to the quantitative performance objectives of DOE O 435.1, "Radioactive Waste Management," to demonstrate reasonable expectation of compliance with these performance objectives [4]. The model development was initiated in 2001 to integrate all numerical and analytical models used in the initial PA, which was used in the licensing of the facility by DOE. The model went through benchmarking against the original PA models, code verification, and validation against field monitoring data. The model is maintained under a software quality assurance plan (SQAP). The SQAP includes protocols for model development, maintenance, approvals, model changes, model versioning, validation and verification, documentation, and model access controls. The model is continuously maintained:

- To update model algorithms and parameter distributions (e.g., new air transport module, radon modeling) based on new information from research and development.
- To incorporate results from field investigations and monitoring (e.g., biotic transport module and parameter distributions).
- To implement new DOE policy (e.g., institutional control period).
- To update disposal cell geometries and addition of new disposal configurations.
- To incorporate the latest DOE-approved dose conversion factors.
- To add new radionuclides not included in the original PA.

The model is used to support the development of the PA Annual Summary Report required under the DOE O 435.1, and to support the RWAP waste profile review process, as discussed in this paper. The model has been used to address the following operational/closure issues:

- Optimization of the final closure cover design
- Disposal cell design
- Operational monitoring and the design of post-closure monitoring
- Climate change impacts on facility performance
- Long-term stability of the facility
- Performance of the facility for long time periods beyond the regulatory compliance period of 1000 years

- Impacts of waste forms and containers on facility performance

PA-Derived Factors

Radionuclide waste concentration limits and the radionuclide available capacities are derived from the PA results. A waste concentration limit is computed for each radionuclide for each of the PA performance objective and scenario (four scenarios for all pathway dose to a member of the public and air pathway dose, radon flux from the site closure cover, and two inadvertent human intrusion scenarios). Eq. 1 shows the computation for a performance objective for dose.

$$WCL_{j,s} = \frac{C_j * H_s}{\max\left(H_{s,j}\ (t)\right)} \qquad \text{Eq. 1}$$

where

WCL_j = waste concentration limit for radionuclide *j* in scenario *s*, Bq m^{-3}

C_j = waste concentration of radionuclide *j* in closure inventory, Bq m^{-3}

H_s = performance objective for scenario *s*, Sv yr^{-1}

$H_{s,j}(t)$ = dose for radionuclide *j* and its progeny for scenario *s*, Sv yr^{-1}

The concentration limits shown in the NNSSWAC and referred to as action levels correspond to the minimum of the limits computed for all scenarios. Action levels allow generators to set limits for waste packages. Also, a sum of fractions calculation can be performed for the radionuclides in a proposed waste profile so that a quick determination can be made for profile approval, as shown in Eq. 2 below.

$$CSOF = \sum_{j=1}^{n} \frac{I_j}{WCL_j} \qquad \text{Eq. 2}$$

where

$CSOF$ = concentration sum of fractions

I_j = concentration of radionuclide in proposed waste stream, Bq m^{-3}

WCL_j = waste concentration limit for radionuclide *j*, Bq m^{-3}

Based on the waste concentration limits, available site capacity (activity) can be computed as in Eq. 3 for each radionuclide.

$$Q_j = WCL_j * V - I_j \qquad \text{Eq. 3}$$

where

Q_j = available site capacity for radionuclide *j*, Bq

V = waste site volume, m^3

I_j = total disposed activity of radionuclide j, Bq

Radionuclide available activity capacity allows for the computation of an activity sum of fractions as in Eq. 4 for a waste profile containing a number of radionuclides.

$$ASOF = \sum_{j=1}^{n} \frac{I_j}{Q_j} \qquad \text{Eq. 4}$$

where

$ASOF$ = sum of fractions for n radionuclides in the waste profile

I_j = activity of radionuclide j in the waste profile, Bq

Q_j = available site capacity for radionuclide j, Bq

SPECIAL ANALYSIS EXAMPLES

Three examples of special analysis performed for waste profile evaluations are provided: (1) profiles with radionuclides not in the PA, (2) profiles including radionuclides with high radon-generation potential, and (3) profiles with high-heat generation radionuclides.

Profiles with Radionuclides Not in the PA

The mix of radionuclides in the proposed waste profiles has been increasingly changing since the PA was first developed as decontamination and decommissioning activities across the DOE complex continue at an accelerated pace. All new radionuclides are tracked in the Area 5 RWMS Inventory model but are not always implemented in the PA model. Recent profiles included eleven new radionuclides with extremely long half-lives in insignificant trace quantities. Some nuclear physics databases list these as stable, including the following eight radionuclides: Tc-98, In-115, Te-123, La-138, Nd-144, and Sm-146, -147, and -148. The following new radionuclides have been added to the model: C-14 gas, Ar-42, Ti-44, Se-79, Ag-108m, Gd-152, Am-242m, Cm-247, and Cf-249 and -251.

A special analysis was recently performed for an activated metal waste stream with two long-lived radionuclides Ar-42 and Ti-44 (32.9-year and 60-year half lives, respectively) that have no action levels. It is shown by special analysis that these radionuclides will decay to negligible levels before release from activated metal is possible. Activated steel is assumed to remain intact for 550 years. After decay for 550 years, the inventories of both radionuclides fall below the 3.7E7 Bq (1 mCi) limit screening level. The waste stream was recommended for approval without conditions.

Radionuclides with High Radon-Generation Potential

A waste stream that consisted of 1,700 m^3 of thorium nitrate was approved for disposal following a special analysis. The thorium nitrate will generate Rn-222 gas and was evaluated using the Area 5 RWMS GoldSim PA model to determine the cover thickness required to reduce the Rn-222 flux density to 20 pCi/m^2 s, which is a performance objective under DOE O 435.1. The waste stream was approved for disposal as a single layer in a disposal cell completed 8.77 m below grade. The cell will have a closure cover of 7.77 m. The usual cover thickness over the shallow land disposal cells is 2.5 m.

Radionuclides with High Heat-Generation Potential

Dozens of radioisotope thermoelectric generators (RTGs) were disposed of in the Area 5 RWMS. The waste streams with RTGs required special analysis due to their Sr-90 inventory and heat generation. Based on three-dimensional heat modeling, all were disposed of at least 2.8 meters (m) below grade, ensuring a 4 m depth of burial at closure. A separation of 3 to 7 m, depending on the RTG inventory, was maintained between the RTGs and other LLW to eliminate any thermal impacts on performance of LLW. Four of the RTGs disposed in 2007 were instrumented with platinum resistance temperature detectors to measure vertical and horizontal temperature profiles around an RTG. The power outputs of these RTGs were 450 watts. The disposal criteria developed through modeling are that RTG surface temperatures remain below 300°C, soil temperatures within 2 m of the surface remain less than 100°C, and temperatures in LLW adjacent to the RTGs are below 30°C. Temperatures at the top of the RTGs were 110°C at the end of 2012.

A recent waste stream included a 500-watt RTG produced by the Byproduct Utilization Program (BUP), known as BUP-500. BUP-500 contains more than 22,000 terabecquerels (TBq) of Sr-90 and is the highest activity Sr-90 RTG ever constructed. Thermal analysis indicated that the heat generated by the buried BUP-500 RTG is sufficient to melt important RTG components and initiate features, events, and processes not addressed in the PA. The waste stream was accepted with removal of the BUP-500 and conditions on the depth and spacing of the remaining RTGs. Another waste stream consisted of two low-activity RTGs classified as LLMW due to the presence of mercury. LLMW must be disposed in Pit 18, a Resource Conservation and Recovery Act–licensed disposal unit with a high density polyethylene liner, located in the northeast corner of the RWMS. Heat effects on the high density polyethylene liner were an additional concern for this waste stream. Thermal analysis indicated that the activity of the mixed-waste RTGs will not create sufficient heat to damage or significantly shorten the lifetime of the Pit 18 liner. The waste stream was accepted for disposal with conditions on the burial depth and spacing.

CONCLUSIONS

The waste profile review process, which is part of the NNSSWAC, allows for an efficient and robust means of decision making for waste disposals at the Area 5 RWMS. The first two steps of this three-step process provide for an efficient review of a waste stream. If the criteria of Steps 1 and 2 are not met, the last step of the review process is performed, which requires running the GoldSim PA model, performing other analysis if necessary, and documenting the results in a special analysis report. The results of the PA model runs and the additional analyses of the non-inventory concerns enable the PA group to assess the impact of disposing the inventory of the proposed waste profile at the Area 5 RWMS and identify operational and design conditions. This last step of the PA review process is the most robust means of making disposal decisions at the NNSS.

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