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METHODOLOGY FOR THE TECHNICAL EVALUATION OF DISPOSAL SYSTEMS FOR GREATER-THAN-CLASS C LOW-LEVEL RADIOACTIVE WASTE

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ABSTRACT

This paper presents the methodology that will be used for the evaluation of alternative disposal concepts for Greater-Than-Class C low-level radioactive waste. The primary focus will be on the technical evaluation of various disposal concepts leading toward the identification of technically feasible disposal systems[3].

INTRODUCTION

The Federal Government was given responsibility by the Low-Level Radioactive Waste Policy Act of 1985 (the Act) to dispose of low-level radioactive waste that exceeds limits set by the Nuclear Regulatory Commission (NRC) for Class C radioactive waste (section 61.55 of title 10, Code of Federal Regulations), but are not within the historical definition of high-level radioactive waste (i.e., spent fuel and first-cycle reprocessing waste). In addition the Act also requires that the Greater-Than-Class C low-level radioactive waste (GTCC LLW) be disposed of in a facility licensed by the NRC.

The Department of Energy (DOE) was given responsibility for disposal of GTCC LLW. The GTCC LLW Program supports the DOE in the long-term management of Greater-Than-Class C LLW.

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1 Presently with Bovay Northwest, Inc.

2 Pacific Northwest Laboratory is operated for the U. S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

3 A disposal system is a single disposal concept or a group of disposal concepts where all of the GTCC LLW is disposed.

SUMMARY OF DISPOSAL SYSTEMS EVALUATION PROCESS

The long-term objective of the disposal task is to provide a licensed facility or facilities for the final disposal of GTCC LLW. In order to choose the "best" disposal concept or group of concepts (a system) to pursue for ultimate disposal, various alternatives will be evaluated. The evaluation process that is being used to meet this objective encompass several assessments each based on different criteria: technical feasibility, economic feasibility, and institutional and regulatory issues. Each of these evaluations act as a gate only allowing those disposal concepts or systems that are deemed feasible based on the assessment criteria to pass through to the next step for further evaluation.

The first objective is to complete an evaluation of the technical feasibility of the alternative disposal concepts. Technical feasibility is based on the ability of a disposal concept to meet performance objectives and technical specifications set in potentially applicable regulations [e.g., 10 CFR 60 and 61, 40 CFR 191 and 193, etc.]. The technical evaluation will be performed in three phases: an initial screening assessment (Gate #1), preliminary performance assessments (Gate #2), and detailed performance assessments (Gate #3). The results of the preliminary and detailed performance assessments (PA) will be used to determine which disposal concepts are technically feasible for each waste type. The technically feasible concepts for each of the waste types will then be grouped into a disposal systems where all of the projected GTCC LLW inventory can be disposed.

The disposal systems that are deemed technically feasible will then under go an economic evaluation. This evaluation will encompass an estimation of the total-life cycle cost of implementing the viable disposal concepts for each GTCC waste type. Then these costs along with the results (e.g., dose to man estimates) from the PAs will be used to perform a cost versus benefit optimization (Gate #4) to identify disposal systems that warrant further evaluation.

The next objective will be to perform an evaluation of the technically and economically feasible disposal system to identify the institutional and regulatory issues (Gate #5) related to each disposal system.

The results of each of the evaluations will used to recommend a disposal system to DOE and to provide the necessary information needed to make the final decision regarding which disposal system will be used for the long-term management of GTCC.

TECHNICAL EVALUATION OF DISPOSAL CONCEPTS

As previously described, the technical evaluation will be completed in three phases. The first phase of the technical evaluation, an initial screening assessment (which has been completed), was a qualitative assessment of 13 disposal concepts. These concepts were:

- shallow-land disposal - 5 m deep trenches with an engineered cover
- near-surface disposal - 10 m deep with an engineered cover
- above-ground vault - above-ground concrete structure with no cover
- below-ground vault - below-grade (5 m) concrete structure with an engineered cover
- modular-concrete canisters - small canisters placed in a 5 m deep trench with an engineered cover
- earth-mounded concrete vault - above-grade vault covered with an engineered earthen mound of at least 5 m
- intermediate depth disposal - 60 m deep boreholes with an engineered cover
- deep geologic disposal - placement in the high-level waste repository
- deep seabed disposal - placement in a geologic formation beneath an ocean floor
- ice sheet disposal - placement into a continental ice sheet
- extraterrestrial disposal - placement into solar orbit
- transmutation - exposing the waste to a flux of neutrons to transform the individual radioisotopes to stable or short-lived isotopes

This assessment will determine which of the initial 13 alternative disposal concepts warrant further evaluation during the second phase of the technical evaluation, the preliminary performance assessments. The preliminary performance assessments will yield rough order of magnitude estimates of impacts resulting from disposal of each GTCC waste type in each disposal concept evaluated. The preliminary PAs will identify waste type versus disposal concept pairs that are acceptable for disposal of untreated GTCC waste. The results will be assessed to determine if changes to the waste form or the addition of more engineered barriers to the disposal site will result in disposal concepts that meet performance objectives, and if these changes are feasible. Such modifications will be evaluated further during the third phase of the technical assessment, the detailed performance assessments.

INITIAL SCREENING ASSESSMENT

The 13 alternative disposal concepts were screened using several criteria to determine if further assessment of the technology is warranted. The primary purpose of the screening was to identify factors that would destine a particular technology to failure. The initial screening was based on the following criteria:

- Degree of Technical Development This criteria was used as an indication of the stage of technical development for each disposal concept based on two factors: (a) the amount of research and development (R&D) required before the concept would be feasible and economical and (b) the amount of testing and demonstration that a particular disposal concept has undergone, and whether the technology is currently being used for disposal of other radioactive waste.
- Degree of Institutional Sensitivity This criteria is a measure of existing or potential institutional factors that would make application of the technology difficult. Institutional barriers include public opinion, public opposition, and political opposition (state, federal, and/or international).

Based on the results of the initial screening assessment, the following concepts will be further evaluated by preliminary PAs (i.e., these have made it through Gate #1):

- shallow-land disposal
- near-surface disposal
- belowground vault
- modular-concrete canisters
- aboveground vault
- earth-mounded concrete vault
- intermediate-depth disposal
- geologic repository

PRELIMINARY PERFORMANCE ASSESSMENTS

This section describes the methodology that is being used for the performance assessments. How the data generated during the assessments will be used is also discussed.

The six near-surface disposal concepts identified for further evaluation during the initial screening assessment will be grouped into two major categories: (1) concepts without an engineered barrier (such as a concrete structure) surrounding the waste, and (2) concepts where the waste is surrounded by engineered concrete structure for the preliminary PAs. Thus the performance of 4 generic disposal concepts will be assessed. These concepts are:

- GTCC LLW disposal in a near-surface facility where no concrete structure surrounds the waste containers
- GTCC LLW disposal in a near-surface facility where the waste containers are placed into a concrete structure (e.g., a concrete vault)
- GTCC LLW disposal in an intermediate depth facility

- GTCC LLW disposal in the deep-geologic repository in a configuration similar to that of HLW

This grouping is done because the modeling that will be performed to estimate release of contaminants from the various disposal concepts will not be sophisticated enough to distinguish between the various near-surface disposal concepts. Therefore, to save on the number of cases that must be modeled the various concepts will be grouped. Although, impacts for the near field exposure scenarios (described later) will be estimated for the different proposed waste disposal depths postulated for the near-surface with no concrete structure (i.e., 5 m and 10 m depths). Far-field impacts will only be estimated for the 4 concepts listed above.

The source term for the preliminary PAs will consist of base case volume projections for GTCC LLW estimated by the Idaho National Engineering Laboratory. The 15 different waste types that constitute the GTCC LLW (e.g., activated metals, sealed sources, compatible trash, etc.) will be grouped into three waste categories for preliminary assessments. Waste types will be grouped by potential contaminant release mechanisms for the various waste types. These categories are:

- **Category 1** which will include all metallic based GTCC LLW components such as activated metals, noncompactible trash, contaminated equipment, sealed sources, foils, mixed-oxide fuel pellets, and thermal sources.
- **Category 2** which will include wastes components where the individual waste species are chemically bound to or incorporated into the waste matrix material; these include ion exchange resins, zeolites, and sludges
- **Category 3** which will include waste components where the waste species are physically incorporated in the waste materials; these include components such as compatible trash, cartridge filters, aqueous liquids, and organic liquids

The release of waste constituents from each of these waste categories will be modeled for all the disposal concepts assessed. No modification of the waste through waste treatment or packaging will be accounted for in the prediction of releases with the exception of the geologic repository where the

waste will be modeled in the emplacement containers postulated for the high-level waste. Release from Category 1 waste will be modeled assuming that the waste matrix corrodes due to contact with infiltrating water, thus releasing contaminants into the advecting water. The resulting concentrations in the advecting water will be checked to assure that solubility limits are not exceeded. Category 2 release of contaminants will be estimated assuming desorption from the waste substrate assuring that solubility limits for each specie is not exceeded. A pure solubility-controlled release from Category 3 waste will be assumed.

Potential impacts will be predicted for 3 (not the geologic repository) of the disposal concepts for both a hypothetical arid western site and wet eastern site, and for each of the three waste categories. The impacts will be predicted by first modeling the release of waste species from the various disposal concepts and estimating their concentrations in various environmental media such as ground water beneath the disposal facilities and in nearby surface water bodies. These estimates will be made using a two-dimensional model of the unsaturated zone to model flow and transport of contaminants from the various disposal concepts, and a three dimensional model of the saturated zone to model flow and transport of contaminants to various hypothetical receptors. The contaminated water from the aquifer is assumed to discharge into a body of surface water where complete mixing occurs.

Exposure of hypothetical individuals to waste species migrating from the disposal sites will be estimated for both near-field and far-field exposure scenarios. These scenarios include exposures where hypothetical individuals intrude into the disposal facilities by drilling into the waste, thus transporting waste to the surface; and the use of ground water or surface water contaminated by waste species leached from the disposal site by infiltrating precipitation. In the intrusion scenario a maximum individual drills into the waste site, brings some of the waste to the surface as drilling spoil, distributes this waste into a garden area, and consumes crops grown in his/her garden. Potential impacts will be estimated for both the driller and the post drilling resident. The far-field scenarios will consist of maximum individuals that consume contaminated water, and crops and livestock raised using the contaminated water. Impacts will be predicted for

two scenarios: (1) the use of contaminated water from the aquifer, and (2) the use of contaminated water from a body of surface water. Resulting doses to exposed individuals will be estimated using International Commission on Radiation Protection Publication 30 methodology, and compared to regulatory limits for doses resulting from disposed radioactive waste (e.g., 10 CFR 61). Doses will be estimated for the near-field scenarios at 100 yr and 500 yr after disposal, and for maximum period during the first 10,000 yr following disposal.

Impacts for the geologic repository will be predicted using site parameters from the currently proposed location for the repository at Yucca Mountain, Nevada. No near-field scenario (i.e., intruder scenario) will be postulated for the repository assessment, due to the extreme depth (approximately 330 m) proposed for the waste. If human exposure to GTCC LLW species occurs, within 10,000 yr after disposal, it is postulated to occur via the use of contaminated ground water down gradient of the repository.

The results from the preliminary PAs for the four disposal concepts and the three waste categories will be interpreted and analyzed in several different ways. First the estimated impacts for the 2 near-surface concepts that were modeled will be reassigned, as appropriate, to the original 6 concepts that were grouped. The appropriated near-field and far-field results will be used for each of the disposal concepts. Next, for each of the 8 disposal concepts, the estimated impacts will be interpreted to determine the contaminants of concern (i.e., the radionuclides that represent a substantial fraction of estimated doses) for each of the waste categories. These results combined with the radionuclide inventories for the various waste types (e.g., sealed sources, compatible trash, etc.) will be used to determine which of the waste types represent problems for disposal within a given concept. Thus "the good, the bad, and the ugly" of the waste types will be identified for each of the disposal concepts.

The estimation of impacts resulting from the disposal of the various waste types into each of the evaluated disposal concepts and their comparison to regulatory limits will then be used to prepare a waste type versus disposal concept technical feasibility matrix. The elements of this matrix will be either a "yes", a "qualified yes", or a "no". A "yes" element indicates that

disposal of the particular waste type in the particular disposal concept is technically feasible for both the wet or dry site without any changes to either the waste form (e.g., via treatment), the disposal facility (e.g., addition of more engineered barriers), or the site itself (e.g., change to a site with a deeper aquifer). A "qualified yes" indicates that the particular waste type disposal concept pair may be feasible if certain changes to the waste form, disposal facility, or disposal site is made. A "no" indicates that the particular waste type disposal concept pair is not feasible. How "qualified yes"s or "no"s are assigned is discussed below.

Waste type versus disposal concept pairs that are assigned a yes have made it through Gate #2.

The estimated impacts and the conceptual model of the various disposal concepts will be assessed to determine whether any changes to the overall disposal system could be made that would appear to make the particular concept technically feasible. This assessment will be a qualitative evaluation of the results based on the degree to which impacts must be lowered to make the concept feasible for the given waste type. The changes that will be assessed include changes to the waste form to slow the release of contaminants, increase the integrity of the disposal package, increased degree or amount of engineered barriers within the disposal facility, and change of site parameters such as a location with lower annual precipitation. Knowledge of the waste treatment processes and engineered barriers, and the sensitivity of final results to various site parameters will be used during this assessment. As an example, if the degree of release must be decreased by about 6 orders of magnitude, it may unreasonable to assume a change in the system could achieve this decrease, but a decrease of several orders of magnitude may be a feasible reduction. Thus, for waste type versus disposal concepts pairs that appear to be unfeasible after the preliminary PAs and the evaluation of the PA results, will be assigned a "no" matrix element. For pairs where it appears that a change in the disposal system (e.g., waste form) would render the estimated impacts acceptable, a "qualified yes" would be assigned. The effects of postulated system changes that would result in a "qualified yes" will be verified via the detailed performance assessments.

DETAILED PERFORMANCE ASSESSMENTS

The detailed performance assessments will use more sophisticated models to predict release from the various disposal facilities. The objective of detailed PAs will be to assess the various changes that are proposed to render a waste type disposal concept technically feasible. In other words, verify whether a "qualified yes" should remain a "qualified yes" or be changed to a "no." The waste type, disposal concept pairs that have been assigned a "yes" or a "qualified yes" at the end of the details PAs, will be deemed to have passed Gate #3.

At the completion of the detailed PAs, the waste type versus disposal concept technical feasibility matrix will be finalized. Based on this matrix, waste type-disposal concept pairs can be grouped into technically feasible disposal systems. A disposal system is a single disposal concept or group of disposal concepts where all of the GTCC LLW inventory can disposed.

ECONOMIC EVALUATION

The objective of the economic evaluation will be to evaluate total system cost to implement the competing disposal concepts. This evaluation will identify optimal groupings of disposal concepts into disposal systems.

This will done by first estimating the cost of siting, designing, licensing, and operating the various technically feasible disposal concepts for the volumes of the different waste types. Next the cost of siting, designing, licensing, and operating any treatment and/or packaging facilities required for disposal of a given waste type via a particular disposal concept will be estimated. Then disposal systems will be developed by grouping of waste type and disposal concept pairs using optimization techniques based on total life-cycle costs of the various systems and the estimated impacts (i.e., dose to man).

INSTITUTIONAL AND REGULATORY ISSUES EVALUATION

The objective of this evaluation will be to identify and evaluate potential institutional and regulatory issues related to implementation of each feasible GTCC LLW disposal system. This evaluation will address

potential public perceptions and concerns (real and perceived), political issues, and regulatory and statutory requirements. The following elements will be addressed during this evaluation:

- Identification of regulatory requirements and issues for disposal of GTCC LLW.
- Identification of the public concerns, based on previous public experiences of other radioactive waste disposal projects. Extrapolation these to the problem of GTCC LLW.
- Identification of potential political issues. Consideration of the views of governors, U.S. Senators and Congressmen, and Congressional committees with jurisdiction over the GTCC disposal.

A preference ranking of the competing disposal systems based on potential institutional and regulatory issues will then be performed, based on the listed elements.

CONCLUSION

Once the three assessments have been completed (technical feasibility, economics, and institutional and regulatory issues), a disposal system will be recommended for the long-term management of GTCC LLW. This recommendation will be documented and supported by the appropriate National Environmental Policy Act (NEPA) documentation. The NEPA documentation will then subjected to the proper process (e.g., public review and comment) before the final decision for GTCC LLW disposal is made.

END

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