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REPOSITORY ISOLATION CRITERIA STUDY RECOMMENDATION REPORT

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1 INTRODUCTION

The Nuclear Waste Policy Act (NWPA) of 1982, as amended, establishes the lines of responsibility in the civilian high-level radioactive waste (HLW) disposal program for the Department of Energy (DOE), the license applicant; the Nuclear Regulatory Commission (NRC), the agency responsible for reviewing the license application (LA) and issuing the license; and the Environmental Protection Agency (EPA), the agency responsible for promulgating radionuclide release standards at the accessible environment for long-term repository performance. Site characterization and licensing of a geologic repository for HLW will require considerable scientific data, knowledge, and expertise be obtained and applied to address complex technical issues under a rigorous schedule and intense public scrutiny.

A fundamental issue in evaluation of DOE's LA by NRC staff is whether the selected mined geologic repository will provide effective postclosure containment and isolation of the HLW in accordance with the requirements set forth by EPA and NRC.

In 1992, the Center for Nuclear Waste Regulatory Analyses (CNWRA) conducted a Repository Functional Analysis (RFA) which identified safety-related functions for a HLW repository (Romine, 1992). The analysis of these safety-related functions was conducted from the viewpoint of a so-called "reasonable scientist or engineer," considering statutory requirements, but avoiding constraints associated with specific repository sites or design approaches. The applicable licensing regulation (10 CFR Part 60) was subsequently examined to determine if it provided NRC with sufficient regulatory authority for all of the identified safety functions. Depending on the level of regulatory coverage provided for each function, they were assigned to one of four correlation categories to support determinations of whether potential regulatory uncertainties existed. The correlation categories were based on a determination of the extent to which the rule (i) recognizes the need for the function and (ii) provides criteria applicable to the function. The four correlation categories were defined as follows:

1. The function is fully covered.

2. 10 CFR Part 60 provides a basis for review and guidance in NRC's reactive program.

3. Regulatory treatment of the function may need to be strengthened to provide a basis for reactive program regulatory guidance.

4. A regulatory basis for the function is missing.

The functions identified were then divided into two groups for future analysis to identify any actual regulatory uncertainties. Those pertaining to preclosure or operational phases of the repository were addressed in the Repository Operational Criteria (ROC) Analysis Report (Hageman and Chowdhury, 1992). Those remaining are related to the postclosure period and are the subject of the Repository Isolation Criteria (RIC) study, for which this report presents the results. NRC guidance focused the RIC effort on the results of the RFA without the need for more detailed functional development, so it did not include the same depth of analysis as the ROC Analysis Report. Section two presents the analysis and associated results, and Section three presents the conclusions. Section four lists the references used to support the study. The attached appendix describes the appropriate regulatory basis for this effort.

2 STUDY RESULTS

The RIC study consists of two activities. Activity 1 was a review and analysis of each of the postclosure safety functions identified by the RFA in correlation categories three or four, (i.e., those identified as potential regulatory uncertainties). The results of this review and analysis form the basis for recommending uncertainty reduction methods to resolve any potential uncertainties associated with the postclosure safety functions identified in correlation categories three or four. Activity 2 consisted of documenting the results of activity 1.

Seven correlation category four functions and no correlation category three functions were identified in the RFA (See Section 1 for definitions of correlation categories). The following postclosure safety-related functions are those identified in correlation category 4 (Section 7 of the RFA).

> Function 7.1.2.1 Delay onset of waste disposal package degradation
> (In the context of function 7.1.2 — controlling the period of postclosure confinement of the waste disposal package.)
>
> Function 7.1.2.1.1 Control condition of waste disposal package material when emplaced
> (In the context of functions 7.1.2 and 7.1.2.1 — controlling the period of postclosure confinement through delaying the onset of waste package degradation.)
>
> Function 7.1.2.1.8 Control postclosure chemical environment of the waste disposal package
> (In the context of functions 7.1.2 and 7.1.2.1 — controlling the period of postclosure confinement through delaying the onset of waste package degradation.)
>
> Function 7.1.2.2.8 Control chemical environment of the waste disposal package
> (In the context of functions 7.1.2 and 7.1.2.2 — controlling the period of postclosure confinement through retarding the rate of waste package degradation.)
>
> Function 7.1.2.3 Limit number of waste disposal package degradation mechanisms
> (In the context of function 7.1.2 — controlling the period of postclosure confinement of the waste disposal package.)
>
> Function 7.2.1.2 Prevent migration of radionuclides to the geologic setting
> (In the context of function 7.2.1 — limiting the cumulative quantity of radionuclides released to the geologic setting.)
>
> Function 7.2.2.5 Limit quantity and rate of fluids contacting waste form
> (In the context of function 7.2.2 — limiting the rate of radionuclide release to the geologic setting.)

Initially, a determination was made that these functions had no regulatory basis in 10 CFR Part 60 because the actual wording of the function(s) did not appear in specific regulatory requirements, and no criteria were provided for them. Consequently, it was concluded that 10 CFR Part 60 did not adequately address the health and safety issues pertaining to these functions. This initial analysis in the RFA was conducted in a very conservative manner to identify all potential postclosure regulatory uncertainties.

The intent of the NRC in developing 10 CFR Part 60 regarding the need for and utility of postclosure active human intervention is stated in NUREG-0804, Section 5.6 (NRC, 1983). In response to comments asking NRC to consider including a long term postclosure performance monitoring program the NRC stated:

> "The Commission considers such measures unnecessary and unlikely to provide useful information on the performance of a geologic repository. The multiple barrier approach the Commission has adopted will result in containment of substantially all of the radioactive materials within the waste package for centuries after permanent closure, the feasibility of obtaining reliable data on subsurface conditions over a period of centuries is questionable, and the practicality of taking remedial action after sealing of the shafts is doubtful. Moreover, the emplacement of remote subsurface monitoring instruments and the provision of data transmission capabilities, could provide additional pathways for release that would make it more difficult to achieve isolation. Rather, the Commission has adopted an approach where the retrievability option is maintained until a performance confirmation program can be completed that will allow the Commission to decide, with reasonable assurance, that permanent closure of the facility, with no further active human intervention with the emplaced wastes, will not cause an unreasonable risk to public health and safety."

From this statement, it is clear the NRC intent is to avoid reliance on postclosure human intervention to ensure isolation.

The NRC's intent is to rely on the siting and design criteria which utilize multiple barriers, repository performance objectives, and the performance confirmation program (all preclosure), as provided for by 10 CFR Part 60, to ensure HLW isolation, and not on postclosure intervention to insure the repository is functioning as intended. The RIC study was conducted using this philosophic underpinning.

The RIC study uses the same criteria and procedures as the RFA but examines whether control of postclosure functions is provided through regulated activities which will take place prior to repository closure. The remainder of the report documents the results of this activity.

It is expected that reviewers will desire to consider each function individually. Therefore, separate, but often similar, rationale is presented for each function which addresses the most likely interpretations of the function. The authors recognize the apparent redundancy that this individual function discussion approach presents to the reader.

Following are the analyses for each function.

FUNCTION 7.1.2.1 DELAY ONSET OF WASTE DISPOSAL PACKAGE DEGRADATION

Since there is to be no provision for postclosure monitoring (NRC, 1983), it will not be possible to actively — measure, control, or influence the waste packages after repository closure. As a result, the emphasis of this analysis focuses on whether a basis for preclosure regulatory action exists (e.g., passive controls) for ensuring this postclosure safety function is carried out. Four general classes of requirements in 10 CFR Part 60 (siting criteria, design criteria, performance objectives, and performance confirmation) have been identified which provide coverage for this function.

The siting criteria in 10 CFR 60.122 and the requirements of 10 CFR 60.21(c)(1)(ii) provide direction on the nature of investigations, measurements, and performance assessments relative to potentially adverse and favorable conditions. These regulatory requirements demand consideration of such attributes of the geologic setting in combinations to determine if the performance objectives relating to isolation of waste will be met. Many of these attributes which must be considered are directly related to the function currently under consideration. Some favorable conditions in 10 CFR 60.122(b), for example, 60.122(b)(1), and 60.122(b)(8), relate to conditions which can help delay the onset of waste package degradation. In turn, the majority of the potentially adverse conditions in 10 CFR 60.122(c) relate to site characteristics which could lead to waste package degradation. For example, 10 CFR 60.122(c)(7) pertains to groundwater conditions which could increase the solubility or chemical reactivity of the engineered barrier system. The site characterization program will have to ensure this and other site conditions are studied and analyses will need to be performed to determine if performance is affected when all other site characteristics are considered. This process will provide assurance that a selected site will not possess conditions which will cause waste package degradation to such an extent as to compromise performance. In conclusion, the siting criteria-related requirements provide some regulation of this function.

However, since the siting criteria may not address all conditions relevant to package degradation, the waste package design requirements in 10 CFR 60.135 provide additional coverage. 10 CFR 60.135(a)(1) specifies that waste package design must be factored into repository performance assessment along with characteristics of the emplacement environment. In fact, the waste package must be designed in the context of the emplacement environment. 10 CFR 60.135 (a)(2) provides a list of factors pertaining to waste package degradation which must be considered in package design. These requirements implicitly address the onset of waste package degradation by requiring the design of a robust waste package which is resistant to conditions identified and anticipated in the emplacement environment. Therefore, a regulatory basis exists for review and guidance regarding delay of waste package degradation through proper design based on the 10 CFR Part 60 waste package design requirements.

The postclosure performance objectives in 10 CFR Part 60, including objectives for the overall system performance in 10 CFR 60.112 and particular barriers in 60.113, through consideration of fundamental safety concerns such as radionuclide releases to the accessible environment, containment, and groundwater travel time, broadly address the safety concerns of waste package degradation. By setting limits for postclosure radionuclide releases to the accessible environment, 10 CFR 60.112 provides a broad level of coverage regarding any aspect of the site or design which would result in releases of radioactive material to the accessible environment above the levels established in the applicable EPA standards. When considering all other factors present at the site, if radionuclide releases from the engineered barrier system (EBS) and the transport through the natural barrier were thought to affect releases to the extent that the EPA standard would not be met, then these requirements provide a basis for review and guidance regarding control of waste package degradation. It is also possible that factors may exist at the site which mitigate the need to emphasize package degradation as a performance issue. Additional standards in 10 CFR 60.113 require the design of the EBS to ensure substantially complete containment [10 CFR 60.113(a)(1)(i)(A), 10 CFR 60.113(a)(1)(ii)(A)] and gradual release rates [10 CFR 60.113(a)(1)(i)(B), 10 CFR 60.113(a)(1)(ii)(B)]. Since accelerated degradation of the waste package could lead to a violation of these standards, a basis exists for review and guidance for control of package degradation.

Performance confirmation requirements in 10 CFR Part 60, Subpart F, specifically require implementation of a performance confirmation program. This program, during the preclosure period,

must assess the validity of the site characterization, waste package design, and performance assessments conducted prior to construction. These aspects are specifically related to control of package degradation. The long duration of this program increases the likelihood that early onset of package degradation can be detected. 10 CFR 60.140(a)(1) requires the program to provide data which indicates whether applicable subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review. Furthermore, 10 CFR 60.143 calls for the establishment of a program for monitoring the condition of the waste packages under conditions representative of the emplacement environment. The repository cannot be closed under conditions where the performance confirmation program has revealed unsatisfactory performance of some aspect of the repository. Thus, the performance confirmation program provides additional assurance that site conditions are as anticipated as well as a means to identify any problems which must be addressed in order to attain satisfactory performance. In either case, control of waste package degradation must be considered and addressed.

In summary, the siting criteria, performance objectives, design criteria, and performance confirmation requirements in 10 CFR Part 60 provide sufficient regulatory basis for review and guidance related to waste package degradation control during the preclosure period, to affect postclosure waste disposal package degradation. Therefore, no regulatory uncertainty exists with respect to this function. Since no specific criterion were identified in 10 CFR Part 60 for controlling the onset of waste package degradation, the correlation category should be classified as "basis exists for regulatory review and guidance" — correlation category two.

FUNCTION 7.1.2.1.1 CONTROL CONDITION OF WASTE DISPOSAL PACKAGE MATERIAL WHEN EMPLACED

Since there is to be no provision for postclosure monitoring (NRC, 1983), it will not be possible to actively — measure, control, or influence the waste packages after repository closure. As a result, the emphasis of this analysis focuses on whether a basis for preclosure regulatory action exists (e.g., passive controls) for ensuring this postclosure safety function is carried out. Three general classes of requirements in 10 CFR Part 60 (design criteria, performance objectives, and performance confirmation) have been identified which provide coverage for this function.

10 CFR 60.135(a)(1) specifies that waste package design must be factored into repository performance assessment along with characteristics of the emplacement environment. In fact, the waste package must be designed in the context of the emplacement environment. 10 CFR 60.135(a)(2) provides a list of factors pertaining to waste package degradation which must be considered in package design. These requirements implicitly address the onset of waste package degradation by requiring the design of a robust waste package which is resistant to conditions identified and anticipated in the emplacement environment. Therefore, a regulatory basis exists for review and guidance regarding delay of waste package degradation through proper design based on the 10 CFR Part 60 waste package design requirements.

The postclosure performance objectives in 10 CFR Part 60, including objectives for overall system performance in 10 CFR 60.112 and particular barriers in 10 CFR 60.113, through consideration of fundamental safety concerns such as radionuclide releases to the accessible environment, containment, and groundwater travel time, broadly address the safety concerns related to control of waste package degradation by controlling the condition of the package material during emplacement. By setting limits for postclosure radionuclide releases to the accessible environment, 10 CFR 60.112 provides a broad level

of coverage regarding any aspect of the site or design which would result in releases of radioactive material to the accessible environment above the levels established in the applicable EPA standards. When considering all other factors present at the site, if radionuclide releases from the EBS and the transport through the natural barrier were thought to affect releases to the extent that the EPA standard would not be met, then these requirements provide a basis for review and guidance regarding control of waste package degradation. It is also possible that factors may exist at the site which mitigate the need to emphasize package degradation as a performance issue. Additional standards in 10 CFR 60.113 require the design of the EBS to ensure substantially complete containment [10 CFR 60.113(a)(1)(i)(A), 10 CFR 60.113(a)(1)(ii)(A)] and gradual release rates [10 CFR 60.113(a)(1)(i)(B), 10 CFR 60.113(a)(1)(ii)(B)]. Since accelerated degradation of the waste package could lead to a violation of these standards, a basis exists for review and guidance of package degradation through control of the material when emplaced.

Quality Assurance (QA) requirements in 10 CFR Part 60, Subpart G, and Performance confirmation requirements in 10 CFR Part 60, Subpart F, require implementation of programs for QA and performance confirmation. The QA program, by including quality control of material (10 CFR 60.150) relevant to all structures, systems and components important to safety (10 CFR 60.151) provides a regulatory basis for review and guidance of waste package material control during emplacement. The performance confirmation program, during the preclosure period, must assess the validity of the site characterization, waste package design, and performance assessments conducted prior to construction. These aspects are specifically related to control of package degradation. The long duration of this program increases the likelihood that early onset of package degradation can be detected. 10 CFR 60.140(a)(1) requires the program provide data which indicates whether applicable subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review. Furthermore, 10 CFR 60.143 calls for the establishment of a program for monitoring the condition of the waste packages under conditions representative of the emplacement environment. The repository cannot be closed under conditions where the performance confirmation program has revealed unsatisfactory performance of some aspect of the repository. Thus, the performance confirmation program provides additional assurance that site conditions are as anticipated as well as a means to identify any problems which must be addressed in order to attain satisfactory performance. In either case, control of waste package degradation must be considered and addressed.

In summary, the design criteria, performance objectives, and quality assurance and performance confirmation requirements in 10 CFR Part 60 provide sufficient regulatory basis for review and guidance related to waste package degradation. Therefore no regulatory uncertainty exists with respect to this function. Since no specific criterion were identified in 10 CFR Part 60 for controlling the onset of waste package degradation, the correlation category for this function should be classified as "basis exists for regulatory review and guidance" — correlation category two.

FUNCTION 7.1.2.1.8 CONTROL POSTCLOSURE CHEMICAL ENVIRONMENT OF THE WASTE DISPOSAL PACKAGE

Since there is to be no provision for postclosure monitoring (NRC, 1983), it will not be possible to actively — measure, control, or influence the waste packages after repository closure. As a result, the emphasis of this analysis focuses on whether a basis for preclosure regulatory action exists (e.g., passive controls) for ensuring this postclosure safety function is carried out. Four general classes of requirements

in 10 CFR Part 60 (siting criteria, design criteria, performance objectives, and performance confirmation) have been identified which provide coverage for this function.

The siting criteria in 10 CFR 60.122 and the requirements of 10 CFR 60.21(c)(1)(ii) provide direction on the nature of investigations, measurements and performance assessments relative to potentially adverse and favorable conditions. These regulatory requirements demand consideration of these attributes of the geologic setting in combinations to determine whether the performance objectives relating to isolation of waste will be met. Many of these attributes which must be considered are directly related to geochemical conditions which can serve to delay the onset of waste package degradation. 10 CFR 60.122(b)(1) states that the nature and rates of geochemical processes, among others, may be a favorable condition. Also, 10 CFR 60.122(b)(8) refers to hydrogeologic conditions in the unsaturated zone which provide low moisture flux in the host rock, a water table below the underground facility, and a hydrogeologic unit above the host rock which would inhibit or divert downward moving water. Such requirements addressing hydrologic conditions are applicable to the chemistry of the emplacement environment because the presence or absence of water can alter the chemistry of this environment. In turn, the majority of the potentially adverse conditions in 10 CFR 60.122(c) relate to site characteristics which could lead to waste package degradation. For example, 10 CFR 60.122(c)(7) pertains to groundwater conditions which could increase the solubility or chemical reactivity of the engineered barrier system. Also, 10 CFR 60.122(c)(8) addresses geochemical processes that would reduce sorption of radionuclides, result in degradation of the rock strength, or adversely affect the performance of the engineered barrier system [i.e., the waste packages and the underground facility (10 CFR 60.2)]. 10 CFR 60.122(c)(9) and 122(c)(10) focus on groundwater conditions in the host rock that are not reducing and evidence of dissolutioning, respectively. The site characterization program will have to ensure these and other site conditions are studied and analyses will need to be performed to determine if performance is affected when all other site characteristics are considered. This process will provide assurance that a selected site will not possess geochemical conditions which will cause waste package degradation to such an extent as to compromise performance. In conclusion, the siting criteria-related requirements provide some regulation of this function.

However, because the siting criteria may not address all conditions relevant to package degradation, the waste package design requirements in 10 CFR 60.135 provide additional coverage. 10 CFR 60.135(a)(1) specifies that waste package design must be factored into repository performance assessment along with characteristics of the emplacement environment. In fact, the waste package must be designed in the context of the emplacement environment. 10 CFR 60.135(a)(2) provides a list of factors pertaining to waste package degradation which must be considered in package design. These requirements implicitly address the onset of waste package degradation by requiring the design of a robust waste package which is resistant to conditions identified and anticipated in the emplacement environment. Therefore, a regulatory basis exists for review and guidance regarding delay of waste package degradation through proper design based on the 10 CFR Part 60 waste package design requirements.

The postclosure performance objectives in 10 CFR Part 60, including objectives for overall system performance in 10 CFR 60.112 and particular barriers in 60.113, through consideration of fundamental safety concerns such as radionuclide releases to the accessible environment, containment, and groundwater travel time, broadly address the safety concerns of waste package degradation. By setting limits for postclosure radionuclide releases to the accessible environment, 10 CFR 60.112 provides a broad level of coverage regarding any aspect of the site or design which would result in releases of radioactive material to the accessible environment above the levels established in the applicable EPA standards. When considering all other factors present at the site, if radionuclide releases from the EBS

must assess the validity of the site characterization, waste package design, and performance assessments conducted prior to construction. These aspects are specifically related to control of package degradation. The long duration of this program increases the likelihood that early onset of package degradation can be detected. 10 CFR 60.140(a)(1) requires the program to provide data which indicates whether applicable subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review. Furthermore, 10 CFR 60.143 calls for the establishment of a program for monitoring the condition of the waste packages under conditions representative of the emplacement environment. The repository cannot be closed under conditions where the performance confirmation program has revealed unsatisfactory performance of some aspect of the repository. Thus, the performance confirmation program provides additional assurance that site conditions are as anticipated as well as a means to identify any problems which must be addressed in order to attain satisfactory performance. In either case, control of waste package degradation must be considered and addressed.

In summary, the siting criteria, performance objectives, design criteria, and performance confirmation requirements in 10 CFR Part 60 provide sufficient regulatory basis for review and guidance related to waste package degradation control during the preclosure period, to affect postclosure waste disposal package degradation. Therefore, no regulatory uncertainty exists with respect to this function. Since no specific criterion were identified in 10 CFR Part 60 for controlling the onset of waste package degradation, the correlation category should be classified as "basis exists for regulatory review and guidance" — correlation category two.

FUNCTION 7.1.2.1.1 CONTROL CONDITION OF WASTE DISPOSAL PACKAGE MATERIAL WHEN EMPLACED

Since there is to be no provision for postclosure monitoring (NRC, 1983), it will not be possible to actively — measure, control, or influence the waste packages after repository closure. As a result, the emphasis of this analysis focuses on whether a basis for preclosure regulatory action exists (e.g., passive controls) for ensuring this postclosure safety function is carried out. Three general classes of requirements in 10 CFR Part 60 (design criteria, performance objectives, and performance confirmation) have been identified which provide coverage for this function.

10 CFR 60.135(a)(1) specifies that waste package design must be factored into repository performance assessment along with characteristics of the emplacement environment. In fact, the waste package must be designed in the context of the emplacement environment. 10 CFR 60.135(a)(2) provides a list of factors pertaining to waste package degradation which must be considered in package design. These requirements implicitly address the onset of waste package degradation by requiring the design of a robust waste package which is resistant to conditions identified and anticipated in the emplacement environment. Therefore, a regulatory basis exists for review and guidance regarding delay of waste package degradation through proper design based on the 10 CFR Part 60 waste package design requirements.

The postclosure performance objectives in 10 CFR Part 60, including objectives for overall system performance in 10 CFR 60.112 and particular barriers in 10 CFR 60.113, through consideration of fundamental safety concerns such as radionuclide releases to the accessible environment, containment, and groundwater travel time, broadly address the safety concerns related to control of waste package degradation by controlling the condition of the package material during emplacement. By setting limits for postclosure radionuclide releases to the accessible environment, 10 CFR 60.112 provides a broad level

and the transport through the natural barrier were thought to significantly affect releases to the extent that the EPA standard would not be met, then these requirements provide a basis for review and guidance regarding control of waste package degradation from chemical conditions in the emplacement environment. It is also possible factors may exist at the site which mitigate the need to emphasize package degradation as a performance issue. Additional regulations in 10 CFR 60.113 require the design of the EBS to ensure substantially complete containment [10 CFR 60.113(a)(1)(i)(A), 10 CFR 60.113(a)(1)(ii)(A)] and gradual release rates [10 CFR 60.113(a)(1)(i)(B), 10 CFR 60.113(a)(1)(ii)(B)]. Since accelerated degradation of the waste package could lead to a violation of these standards, a basis exists for regulatory control of package degradation through preclosure control of postclosure geochemical conditions.

Performance confirmation requirements in 10 CFR Part 60, Subpart F, specifically require implementation of a performance confirmation program. This program, during the preclosure period, must assess the validity of the site characterization, waste package design, and performance assessments conducted prior to construction. These aspects are specifically related to geochemical conditions and package degradation. The long duration of this program increases the likelihood that early onset of package degradation can be detected. 10 CFR 60.140(a)(1) requires the program to provide data which indicates whether applicable subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review. For example, the performance confirmation program must collect information on changes in subsurface conditions [10 CFR 60.141(b)], backfill, borehole and shaft seals [10 CFR 60.142(c) and (d)], and waste package condition (10 CFR 60.143). The repository cannot be closed under conditions where the performance confirmation program has revealed unsatisfactory performance of some aspect of the repository. Thus, the performance confirmation program provides assurance that site conditions are as anticipated as well as a means to identify any problems which must be addressed in order to attain satisfactory performance. In either case, waste package degradation must be considered and addressed.

In summary, the siting criteria, design criteria, performance objectives, and performance confirmation requirements in 10 CFR Part 60 provide sufficient regulatory basis for addressing package degradation due to the chemical environment of the waste package. Therefore, no regulatory uncertainty exists with respect to this function. Since specific criteria were identified in 10 CFR Part 60 which serve to control the postclosure chemical environment of the waste package [i.e, siting criteria in 10 CFR 60.122(b)(1), (b)(8), (c)(7), (c)(8), (c)(9), (c)(10)] the correlation category for this function should be classified as "function is fully covered" — correlation category one. Other applicable requirements discussed do not provide specific criteria, but can support review and guidance regarding control of the postclosure waste package chemical environment.

FUNCTION 7.1.2.2.8 CONTROL CHEMICAL ENVIRONMENT OF THE WASTE DISPOSAL PACKAGE

Since there is to be no provision for postclosure monitoring (NRC, 1983), it will not be possible to actively — measure, control, or influence the waste packages after repository closure. Furthermore, this function has been identified as a postclosure safety function in the RFA, and despite the lack of specific language to indicate this in the text of the function (as is done in 7.1.2.1.8) the emphasis of this analysis focuses on whether a basis for preclosure regulatory action exists (e.g., passive controls) for ensuring this postclosure performance function is carried out. Four general classes of requirements in 10 CFR Part 60 (siting criteria, design criteria, performance objectives, and performance confirmation) have been identified which provide coverage for this function.

The siting criteria in 10 CFR 60.122 and the requirements of 10 CFR 60.21(c)(1)(ii) provide direction on the nature of investigations, measurements and performance assessments relative to potentially adverse and favorable conditions. These regulatory requirements demand consideration of these attributes of the geologic setting in combinations to determine whether the performance objectives relating to isolation of waste will be met. Many of these attributes which must be considered are directly related to geochemical conditions which can serve to retard the rate of waste package degradation. 10 CFR 60.122(b)(1) lists the nature and rates of geochemical processes among others as a favorable condition. Also, 10 CFR 60.122(b)(8) refers to hydrogeologic conditions in the unsaturated zone which provide low moisture flux in the host rock, a water table below the underground facility, and a hydrogeologic unit above the host rock which would inhibit or divert downward moving water. (Such requirements addressing hydrologic conditions are applicable to the chemistry of the emplacement environment because the presence or absence of water can alter the chemistry of this environment.) In turn, the majority of the potentially adverse conditions in 10 CFR 60.122(c) relate to site characteristics which could lead to waste package degradation. For example, 10 CFR 60.122(c)(7) pertains to groundwater conditions which could increase the solubility or chemical reactivity of the engineered barrier system. Also, 10 CFR 60.122(c)(8) addresses geochemical processes that would reduce sorption of radionuclides, result in degradation of the rock strength, or adversely affect the performance of the engineered barrier system [i.e., the waste packages and the underground facility (10 CFR 60.2)]. 10 CFR 60.122(c)(9) and 122(c)(10) focus on groundwater conditions in the host rock that are not reducing and evidence of dissolutioning. The site characterization program will have to ensure site conditions that affect the near field EBS characterization are studied and analyses will need to be performed to determine if performance is affected when all other site characteristics are considered. This process will provide assurance that a selected site will not possess geochemical conditions which will cause waste package degradation to such an extent as to compromise performance. In conclusion, the siting criteria-related requirements provide some regulation of this function.

However, since the siting criteria may not address all conditions relevant to package degradation, the waste package design requirements in 10 CFR 60.135 provide additional coverage. 10 CFR 60.135(a)(1) specifies that waste package design must be factored into repository performance assessment along with characteristics of the emplacement environment. In fact, the waste package must be designed in the context of the emplacement environment. 10 CFR 60.135 (a)(2) provides a list of factors pertaining to waste package degradation which must be considered in design of the waste package and its component parts [e.g., shielding, packing, and other surrounding materials (10 CFR 60.2)]. These requirements implicitly address the onset of waste package degradation by requiring the design of a robust waste package and surrounding material which are resistant to conditions identified and anticipated in the emplacement environment. Therefore, a regulatory basis exists for review and guidance regarding retardation of waste package degradation by control of the waste package chemical environment through proper design based on the 10 CFR Part 60 waste package design requirements.

The postclosure performance objectives in 10 CFR Part 60, including objectives for overall system performance in 10 CFR 60.112 and particular barriers in 60.113, through consideration of fundamental safety concerns such as radionuclide releases to the accessible environment, containment, and groundwater travel time broadly address the safety concerns of waste package degradation. By setting limits for postclosure radionuclide releases to the accessible environment, 10 CFR 60.112 provides a broad level of coverage regarding any aspect of the site or design which would result in releases of radioactive material to the accessible environment above the levels established in the applicable EPA standards. When considering all other factors present at the site, if radionuclide releases from the EBS and the transport through the natural barrier were thought to significantly affect releases to the extent that

the EPA standard would not be met, then these requirements provide a basis for review and guidance regarding control of waste package degradation from chemical conditions in the emplacement environment. It is also possible factors may exist at the site which mitigate the need to emphasize package degradation as a performance issue. Additional regulations in 10 CFR 60.113 require the design of the EBS to ensure substantially complete containment [10 CFR 60.113(a)(1)(i)(A), 10 CFR 60.113(a)(1)(ii)(A)] and gradual release rates [10 CFR 60.113(a)(1)(i)(B), 10 CFR 60.113(a)(1)(ii)(B)]. Since accelerated degradation of the waste package could lead to a violation of these standards, a basis exists for regulatory control of package degradation through preclosure control of postclosure geochemical conditions.

Performance confirmation requirements in 10 CFR Part 60, Subpart F, specifically require implementation of a performance confirmation program. This program, during the preclosure period, must assess the validity of the site characterization, waste package design, and performance assessments conducted prior to construction. These aspects are specifically related to geochemical conditions and package degradation. The long duration of this program increases the likelihood that the rate of package degradation can be determined. 10 CFR 60.140(a)(1) requires the program to provide data which indicates whether applicable subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review. Information must be collected on changes in subsurface conditions [10 CFR 60.141(b)], backfill, borehole and shaft seals [10 CFR 60.142(c) and (d)], and waste package condition (10 CFR 60.143). The repository cannot be closed under conditions where the performance confirmation program has revealed unsatisfactory performance of some aspect of the repository. Thus, the performance confirmation program provides assurance that site conditions are as anticipated as well as a means to identify any problems which must be addressed in order to attain satisfactory performance. In either case, waste package degradation must be considered and addressed.

In summary, the siting criteria, performance objectives, design criteria, and performance confirmation requirements in 10 CFR Part 60 provide sufficient regulatory basis for addressing waste package degradation through control of the chemical environment of the waste package. Therefore, no regulatory uncertainty exists with respect to this function. Since specific criteria were identified in 10 CFR Part 60 which serve to control the postclosure chemical environment of the waste package [i.e, siting criteria in 10 CFR 60.122(b)(1), (b)(8), (c)(7), (c)(8), (c)(9), (c)(10)] the correlation category for this function should be classified as "function is fully covered" — correlation category one. Other applicable requirements discussed do not provide specific criteria, but can support review and guidance regarding control of the postclosure waste package chemical environment.

FUNCTION 7.1.2.3 LIMIT NUMBER OF WASTE DISPOSAL PACKAGE DEGRADATION MECHANISMS

While analysis seems to produce a technical basis for limiting the "number" of mechanisms of waste package degradation, there is also general agreement in the scientific and engineering community that the "effect" of the degradation mechanism or mechanisms, regardless of their number, is the determining factor on waste package performance. This principle is borne out in the design philosophy of "defense in depth" through the inclusion of multiple barriers to contain the waste. Each barrier brings with it additional degradation mechanisms, but the overall waste package performance is improved. Since limiting the number of disposal mechanisms may not be an available method for prolonging the life of the waste package, this is not a legitimate safety function, and it should be deleted. The "effect" of the degradation mechanism or mechanisms is covered under RFA functions 7.1.1.1 (Resist waste disposal

package degradation) and 7.1.2.2 (Retard rate of waste disposal package degradation), as well as others covering the delay of onset of degradation and limiting the rate of degradation. Because of this existing coverage under other functions which have adequate regulatory control associated with the waste package through 10 CFR 60.113 and 10 CFR 60.135, this function should be removed from the list of postclosure safety functions and from characterization as a potential regulatory uncertainty.

FUNCTION 7.2.1.2 PREVENT MIGRATION OF RADIONUCLIDES TO THE GEOLOGIC SETTING

This function is unique because the term *prevent* is an absolute. This raises questions regarding the technical feasibility of such a function. Total prevention of radionuclide releases for an apparently infinite time period is currently technically infeasible given our present knowledge of the behavior of engineered and natural systems. Therefore, the literal interpretation of *prevent* is not considered meaningful nor the likely intent of the original author of the RFA. In addition, the use of *limit* is more consistent with the wording of other functions in the RFA. Therefore, we recommend the term *limit* be substituted for *prevent* to present a more technically realistic safety concern.

While there is no requirement in Part 60 which specifically requires *prevention* of radionuclide migration, there are requirements in the performance objectives in 10 CFR 60.113, which focus on *limiting* migration of radionuclides. Through the imposition of release rates, 10 CFR 60.113(a)(1)(ii)(B) provides regulatory coverage and criteria for limiting migration of radionuclides to the geologic setting. Therefore, no uncertainty exists and the correlation category for this function should be classified as "function is fully covered" — correlation category one.

FUNCTION 7.2.2.5 LIMIT QUANTITY AND RATE OF FLUIDS CONTACTING WASTE FORM

Since there is to be no provision for postclosure monitoring (NRC, 1983), it will not be possible to actively — measure, control, or influence the waste packages after repository closure. As a result, the emphasis of this analysis focuses on whether a basis for preclosure regulatory action exists (e.g., passive controls) for ensuring this postclosure safety function is carried out. Four general classes of requirements in 10 CFR Part 60 (siting criteria, design criteria, performance objectives, and performance confirmation) have been identified which provide coverage for this function.

The siting criteria in 10 CFR 60.122 and the requirements of 10 CFR 60.21(c)(1)(ii) provide direction on the nature of investigations, measurements, and performance assessments relative to potentially adverse and favorable conditions. These regulatory requirements demand consideration of such attributes of the geologic setting in combinations to determine whether the performance objectives relating to isolation of waste will be met. Many of these attributes which must be considered are directly related to limitation of fluid quantity and rate. Some favorable conditions in 10 CFR 60.122(b), for example, 60.122(b)(1), and 60.122(b)(8), relate to conditions which can help limit both the rate and quantity of fluid contact — such as; a determination that the nature and rates of tectonic, hydrogeologic, geochemical, geomorphic (or any of such processes) operating within the geologic setting during the Quaternary Period, when projected, do not affect or would favorably affect the ability of the geologic repository to isolate the waste; hydrogeologic conditions in the unsaturated zone which provide low moisture flux in the host rock; a water table below the underground facility; a hydrogeologic unit above the host rock which would inhibit or divert downward moving water; host rock that permits free drainage; and a climatic regime in which the average annual historic precipitation is a small percentage of the

average annual evapotranspiration. In turn, a number of the potentially adverse conditions in 10 CFR 60.122(c) relate to site characteristics which could lead to excessive quantity or rate of fluids contacting the waste form. For example, requirements exist which call for an assessment of the potential for flooding [10 CFR 60.122(c)(1)]; potential for foreseeable human activity to adversely affect the groundwater flow system [10 CFR 60.122(c)(2)]; structural deformation which could affect the regional groundwater flow system [10 CFR 60.122(c)(4)]; potential for the water table to rise sufficiently so as to cause saturation of the underground facility [10 CFR 60.122(c)(22)]; and potential for changes in hydrologic conditions resulting from reasonably foreseeable climatic changes [10 CFR 60.122(c)(6)]. 10 CFR 60.122(c)(7) pertains to groundwater conditions which could increase the solubility or chemical reactivity of the engineered barrier system — a result which can contribute to early waste package failure and increases the potential for fluids to contact the waste form. The site characterization program will have to study these and other site conditions and analyses will need to be performed determine if performance is affected when all other site characteristics are considered. This process will provide assurance that a selected site will not possess conditions which contribute to fluid contact with the waste form to such an extent as to compromise performance. In conclusion, the siting criteria provides some regulation of this function.

However, because the siting criteria may not address all fluid conditions relevant to package degradation, the waste package design requirements in 10 CFR 60.135 provide additional coverage. 10 CFR 60.135(a)(1) specifies that waste package design must be factored into repository performance assessment along with characteristics of the emplacement environment. In fact, the waste package design must be designed in the context of the emplacement environment. 10 CFR 60.135(a)(2) provides a list of factors pertaining to waste package degradation which must be considered in package design. These requirements implicitly limit the quantity and rate of fluid contacting the waste form by requiring the design of a robust waste package which protects the waste form from fluid which may be identified or anticipated in the emplacement environment. Therefore, a regulatory basis exists for review and guidance regarding limitation of the rate and quantity of fluid contacting the waste form through proper design based on the 10 CFR Part 60 waste package design requirements.

The postclosure performance objectives in 10 CFR Part 60, including objectives for overall system performance in 10 CFR 60.112 and particular barriers in 60.113, through consideration of fundamental safety concerns such as radionuclide releases to the accessible environment, containment, and groundwater travel time, broadly address the safety concerns of function 7.2.2.5. By setting limits for postclosure radionuclide releases to the accessible environment, 10 CFR 60.112 provides a broad level of coverage regarding any aspect of the site or design which would result in releases of radioactive material to the accessible environment above the levels established in the applicable EPA standards. When considering all other factors present at the site, if the rate and quantity of fluid contact with the waste form were thought to affect releases to the extent that the EPA standard would not be met, then these requirements provide a basis for review and guidance regarding the quantity and rate of fluids which contact the waste form. It is also possible factors may exist at the site which mitigate the need to emphasize fluid contact as a performance issue. Additional standards in 10 CFR 60.113 require the design of the EBS to ensure substantially complete containment [10 CFR 60.113(a)(1)(i)(A), 10 CFR 60.113(a)(1)(ii)(A)] and gradual release rates [10 CFR 60.113(a)(1)(i)(B), 10 CFR 60.113(a)(1)(ii)(B)]. Since fluid contact with the waste form could lead to a violation of these standards, a basis exists for regulatory review and guidance regarding the quantity and rate of fluids which contact the waste form.

Performance confirmation requirements in 10 CFR Part 60, Subpart F, specifically require implementation of a performance confirmation program. This program, during the preclosure period,

must assess the validity of the site characterization, waste package design, and performance assessments conducted prior to construction. These aspects are specifically related to control of the quantity and rate of fluids which contact the waste form. For example, the performance confirmation program must collect information on changes in groundwater and the rate of water inflow into subsurface areas [10 CFR 60.141(c)] —- aspects which are highly relevant to the determination of the quantity and rate of fluid contact with the waste form in the emplacement environment and waste package degradation mechanisms which could expose the waste form to such environmental conditions. There are also requirements for testing borehole and shaft seals [10 CFR Part 60.122(d)] which help to reduce the potential for these structures to become pathways for fluid transport. The repository cannot be closed under conditions where the performance confirmation program has revealed unsatisfactory performance of some aspect of the repository. Thus, the performance confirmation program provides additional assurance that site conditions are as anticipated as well as a means to identify any problems which must be addressed in order to attain satisfactory performance. In either case, fluid contact with the waste form must be considered and addressed.

In summary, the siting criteria, performance objectives, design criteria, and performance confirmation requirements in 10 CFR Part 60 provide sufficient regulatory basis for review and guidance regarding the quantity and rate of fluid contact with the waste package. Therefore, no regulatory uncertainty exists with respect to this function. Since no specific criterion were identified in 10 CFR Part 60 for controlling the onset of waste package degradation, the correlation category for this function should be classified as "basis exists for regulatory review and guidance" — correlation category two.

3 CONCLUSIONS

In conducting activity 1, as evidenced above, a number of questions were raised as to whether the functions in question were correctly categorized. It appears that the original definition of safety-related functions and subsequent examination for coverage by 10 CFR Part 60 were done in an unnecessarily conservative manner. Examination of the wording of the functions under consideration reveals a requirement for control of conditions which could affect isolation of waste. While in some circumstances it may be possible to exert control of these postclosure conditions by actions conducted in the preclosure time period (i.e., engineering design and passive controls incorporated in the EBS), the nature of the wording of the functions as originally literally interpreted in the RFA seems to imply such control could be conducted in the postclosure time period. Clearly this was not the stated intent of the NRC (NRC, 1983). Since the functions may be addressed by use of engineering design and passive controls initiated in the preclosure period, by site selection requirements, and by performance assessments and confirmation programs, 10 CFR Part 60 coverage of these functions was reconsidered. The results indicate requirements exist in 10 CFR Part 60 which form an adequate basis for the NRC to provide regulatory control. This is true even though the wording in the regulation does not exactly match the specific, albeit arbitrary, language of the functions.

In conclusion, revision of the correlation categories is recommended for all seven of the functions in this report. Functions 7.1.2.1.8, 7.1.2.2.8, and 7.2.1.2 are fully covered from a regulatory basis, functions 7.1.2.1, 7.1.2.1.1, and 7.2.2.5 have an existing basis for regulatory review and guidance; and function 7.1.2.3 is recommended for removal from classification as a postclosure function affecting health and safety.

The combination of adequate preclosure regulatory control through site selection and engineered barrier system design criteria, a performance confirmation program, and the lack of intent to provide for human intervention during the postclosure period result in the conclusion that there are no regulatory uncertainties associated with the postclosure functions identified in the RFA. Because of the results of the analysis, defining uncertainty reduction strategy in Activity 1 of this effort was not needed.

The issue of postclosure oversight of a HLW repository based on active institutional controls has recently been addressed in the Energy Policy Act of 1992. The Act directs the National Academy of Sciences (NAS) to consider the issue as part of their assessment of EPA's HLW disposal standards and make recommendations no later than December 31, 1993. The EPA is directed to promulgate standards consistent with the NAS findings in the following year. Given that NRC standards in 10 CFR Part 60 must conform to the revised EPA standards, and that EPA currently defines *active institutional controls* to include monitoring performance parameters [40 CFR 191.12(f)(4)], actions in response to the Energy Policy Act may influence the current NRC position regarding postclosure monitoring and may also impact the conclusions of this report. Therefore, an assessment of impact may be appropriate when the NAS recommendations have been published.

4 REFERENCES

10 CFR Part 60 (U.S. Code of Federal Regulations). *Disposal of High-Level Radioactive Wastes in Geologic Repositories*. Part 60, Chapter I, Title 10, "Energy".

40 CFR Part 191 (U.S. Code of Federal Regulation). *Environmental and Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes*. Part 191, Chapter I, Title 40, "Protection of Environment".

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