NATIONAL ACADEMY OF SCIENCES COMMITTEE ON TECHNICAL BASES
FOR YUCCA MOUNTAIN STANDARDS
MAY 27, 1993

# U.S. NUCLEAR REGULATORY COMMISSION STAFF VIEWS ON ENVIRONMENTAL STANDARDS FOR DISPOSAL OF HIGH-LEVEL WASTES

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## I. INTRODUCTION

Thank you for the opportunity to present the U.S. Nuclear Regulatory Commission (NRC) staff's views on the major issues involved in developing standards for disposal of high-level wastes (HLW). Under the provisions of the Nuclear Waste Policy Act (as well as earlier legislation), the NRC is one of three Federal agencies with a role to play in disposal of HLW. The Department of Energy has the responsibility for actual disposal of HLW -- developing a repository and operating it. The U.S. Environmental Protection Agency (EPA) has been charged with developing the environmental standards that will be used to evaluate the safety of the repository developed by DOE. NRC is the implementor -- the regulatory agency that will determine whether DOE's proposal does, in fact, comply with the requirements of EPA's standards.

The NRC's regulatory role causes the NRC to have a strong interest in both the form and the content of HLW standards. Of course, the NRC's first interest is protection of public health and safety. We look to EPA's standards to define an adequate level of public health protection. When implementing EPA's standards, the NRC staff's major concern is with the clarity of the standards and the practicality of evaluating compliance with them during licensing. However, the NRC staff also recognizes a strong national interest in proceeding with HLW



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disposal in a manner that is adequately safe. The NRC staff therefore is concerned that the standards should provide a level of safety that is sufficient to adequately protect future generations, but is not so stringent that demonstrating compliance with the standards becomes needlessly costly or time consuming. With those basic concerns in mind, let me now turn to the basic safety goal for HLW disposal, and then discuss the major issues the NRC staff believes will be important in formulating standards to achieve that basic goal.

## II. THE BASIC SAFETY GOAL

More than a decade ago, the Nuclear Waste Policy Act set up a national program for development of deep geologic repositories for disposal of high-level radioactive wastes (HLW). This decision was not reached lightly. A wide range of alternative disposal technologies, ranging from subseabed disposal to disposal in space, had earlier been evaluated by the U.S. Department of Energy (DOE). After selection of repository disposal as the preferred technology, the safety of deep geologic disposal of HLW was reviewed twice by the U.S. Nuclear Regulatory Commission (NRC). First, the Waste Confidence Decision of 1984 found reasonable assurance that safe disposal of HLW in a repository is technically feasible. Then, in 1990, the NRC reviewed and reaffirmed its earlier views on the technical feasibility of safe repository disposal. And, the U.S. has not been alone in its pursuit of repository disposal. Other nations with substantial nuclear power programs have also endorsed the concept of disposal of HLW in deep geologic repositories.

One might reasonably ask the question "On what basis has this generation, today, selected repository disposal and evaluated its safety?" The answer lies, I think, in what can be called the "Societal Pledge to Future Generations." The Pledge is really very simple. First, it assumes that future societies will be just as concerned as we are today about the potential health hazards of radiation exposure. No more and no less. The Pledge then promises to provide future societies with the same protection from radiation we would expect for ourselves. No more and no less. The Pledge further promises to provide that protection in a way that does not impose burdens on future societies. In other words, future societies will not need to take special precautions to protect themselves from the radioactive materials we generate today. Instead, we will do today whatever is necessary to ensure an adequate level of radiation protection. This Pledge is, I believe, what decision-makers in the U.S. and other nations had in mind when deep geologic disposal was selected as the preferred technology and was declared to be safe.

Of course, the Pledge I just described is rather general and lacks many important details. Development of those details, in the form of recommendations for environmental standards, is the charter of this panel of the National Academy of Sciences. Many difficult issues must be addressed by the panel, including several that I will discuss in a moment. I think, however, that the difficulty of some issues can be reduced by accepting the Societal Pledge I described. When considering environmental standards, we should not try to forecast possible cures for cancer, capabilities to detect and correct genetic abnormalities, long-term changes in societal lifestyles and preferences, and so on. It will be difficult enough to predict the geologic evolution of a repository site. Trying to also predict human and societal evolution over thousands of years, and to litigate those predictions during licensing, seems to me to be both unproductive and unnecessary. Instead, we should assume that human beings and their social institutions will remain much as they are today and, based on that assumption, we should provide for the future the same protection from radiation we would demand for ourselves. Trying to speculate about the ways in which humans or societies might change over thousands of years in the future, and to tailor standards to those changes, seems a very difficult undertaking with little chance of success.

## III. THE ISSUES

As I see it, there are at least seven major issues that need to be addressed by this panel. Let me discuss each of these issues.

(1) Health-based versus technology-based standards. Any environmental standard should have as its underlying basis a safety goal for the allowable health risk to an individual or a population. Perhaps the most fundamental issue facing this panel is the way in which the safety goal should be determined. When EPA developed its 1985 standards, the underlying safety goal was largely based on EPA's analyses of the waste isolation capabilities of several hypothetical HLW repositories. EPA estimated the health effects that might be caused by those repositories, compared that level of health effects to the estimated impacts of unmined uranium ore, natural background radiation and similar reference points, and then required that any real repository perform at least as well as EPA's hypothetical repositories. Thus, the safety goal underlying EPA's 1985 standards can be termed "technology-based" because it was derived from EPA's analyses of the waste isolation capabilities of repositories.

The advantage of a technology-based safety standard is that it largely eliminates questions about whether the projected impacts of a repository will be "as low as reasonably achievable" (ALARA). After all, the whole purpose of a technology-based standard is to require the best level of performance that a particular technology is thought to be able to provide. Thus, a technology-based standard can largely eliminate any need for a time-consuming and controversial ALARA analysis during the licensing review for a specific repository. The disadvantage of a technology-based standard is the potential for such a standard to be overly stringent if EPA misjudges the waste isolation capability of repositories or the costs of achieving compliance. Failure to recognize the potential for gaseous release of carbon-14 from an unsaturated zone repository illustrates the vulnerability of technology-based standards when applied to a new or evolving technology like HLW disposal. There also is no guarantee that a purely technology-based standard would be adequately protective.

In contrast to EPA's technology-based safety goal, the International Commission on Radiological Protection (ICRP) has recommended a "health-based" safety goal. The ICRP examined other risks accepted by society and, on that basis, developed recommended dose and risk limits for individuals who might be exposed to releases from a repository in the future. The ICRP's recommendations can be characterized as "health-based" because they represent the judgment of the ICRP as to the highest level of health risk that any person should ever be subjected to, regardless of the costs or technical difficulties of achieving compliance.

The Energy Policy Act asks this panel to consider whether a "health-based standard" would be reasonable. In my view, use of the term "health-based" refers to the type of ty goal recommended by the ICRP, in contrast to the technology-based health goal previously adopted by EPA. As I stated earlier, one of the most fundamental issues facing this panel is whether a health-based safety goal, like that recommended by the ICRP, would provide a reasonable basis for EPA's HLW standards and whether such a basis would be preferable to the technology-based approach previously used by EPA.

In the NRC staff's view, EPA should reduce the emphasis placed on technical achievability when deriving its standards. The "carbon-14 issue" illustrates the vulnerability of technology-based standards to new information. For a new undertaking, like a HLW repository, there is a real potential for technology-based standards to be unreasonably stringent if all significant releases cannot be identified and included in the derivation of those standards. On the other hand, there is no guarantee that technology-based standards will be adequately protective. For these reasons, the NRC staff has recommended to EPA that much more emphasis be placed on health-based reasoning when deriving EPA's HLW standards.

(2) Individual versus population protection. The second major issue facing this panel involves the type of radiation protection to be emphasized by EPA's standards -- protection for individuals or protection for the population as a whole. EPA's 1985 standards emphasized protection of populations by imposing "containment requirements" that limited the cumulative amount of radioactive material released over 10,000 years. In contrast, the Energy Policy Act now asks whether a standard, "based upon doses to individual members of the public," would be reasonable.

EPA's decision to base its 1985 standards on population impacts rather than on protection of individuals was EPA's most significant departure from the traditional concepts of radiation protection, from the recommendations of advisory groups like the ICRP, and from the practices of other nations. EPA's defense of its decision was two-fold -- practicality and a desire to emphasize waste containment rather than dilution.

EPA's practicality concern deserves close attention by this panel. Ten years ago, the Waste Isolation Systems Panel of the National Academy of Sciences warned that large individual doses can occur if humans consume contaminated groundwater in the vicinity of a HLW repository. The reason is simple -- groundwater flow rates are too low to provide significant dilution of potential releases. When trivial doses were estimated for a repository at Hanford, it was assumed that releases would be diluted in the Columbia River. There is no Columbia River near Yucca Mounta  In fact, at Yucca Mountain, consumption of groundwater may be the most likely pathway for repository releases to reach humans. Since groundwater flow provides little dilution of releases, unacceptably large doses may be predicted to occur unless a Yucca Mountain repository performs much better than would have been required by EPA's 1985 standards.

There are strong arguments in favor of an individual protection standard, either as a supplement to EPA's cumulative release limits, or as a replacement for those release limits. One of the first principles of radiation protection has always been to provide an adequate level of protection for each individual potentially exposed to radiation. Questions have been raised about EPA's 1985 standards because those standards depart from that tradition. When this panel considers whether to recommend adoption of an individual dose standard, the panel will also need to face the challenge of finding practical way to make such a standard workable for a repository where no large river is available to dilute potential releases, but which has clear advantages for containment of wastes.

The NRC staff considers that radiation protection for individuals should be a part of EPA's standards. However, it will be very important to ensure that an individual protection standard is applied in a reasonable manner. An individual protection standard should not attempt to protect all individuals, under all conceivable circumstances, at all times in the future. For example, it does not seem reasonable to try to protect a hypothetical farm family located at the boundary of a Yucca Mountain repository, when it is unlikely that such a farm family will ever exist. Instead, a more realistic scenario would involve exploitation of groundwater near Yucca Mountain as a supplement to the municipal water supply for regional populations. Water consumers in the region would then form the critical group whose doses would be limited by an individual protection standard.

<u>(3) Fundamental versus derived standard.</u> Development of environmental standards usually begins with establishment of an underlying basic safety goal, expressed in terms of an allowable dose or health risk to an individual or a population. However, it is not necessary to express the standard directly in terms of that fundamental goal. Instead, the standard can be expressed in terms of a derived quantity, such as quantity or concentration of radioactive material released to the environment. The advantage of a derived, release limit standard is simplicity. Evaluations of compliance need not predict who will live where, or

how they will live, for thousands of years into the future. The disadvantage of a derived standard is the possibility that conditions near a repository will be different from those assumed when deriving the standard from the basic safety goal. If so, the actual health risk caused by releases from a repository might be significantly different from the basic safety goal.

As we all know, EPA's 1985 standards were expressed in terms of release limits derived from EPA's analyses of the expected performance of hypothetical repositories. Those release limits were controversial, at least in part, because the release limits were derived using a "world-average" biosphere that bore little resemblance to the biosphere likely to exist near Yucca Mountain. Thus, the actual number of health effects that might be caused by releases from Yucca Mountain might also bear little resemblance to EPA's health effects goal. Now, the Energy Policy Act asks this panel to consider whether a standard "based upon doses" to individual members of the public is reasonable. I interpret the phrase "based upon doses" to allow this panel to consider derived standards, such as limits on concentrations of radionuclides released to the environment, as well as standards that directly limit doses. The issue before this panel is whether the simplicity of derived standards, and the relative ease of evaluating compliance with them during licensing, outweighs the potential for derived standards to depart from the underlying basic safety goal.

The NRC staff has supported a derived standard (e.g., a limit on radionuclide releases) because such a standard would be easier to implement during licensing than a fundamental standard expressed in terms of doses or health risks. Of course, if a derived standard is to be used, it would be necessary to avoid unrealistic assumptions in the derivation of the standard. A fundamental (dose or health risk) standard would also be acceptable, provided that such a standard could be implemented using some type of "static" or "reference" biosphere. The NRC staff would object to any fundamental standard that permitted unlimited speculation about future human locations, lifestyles and societal conditions.

(4) Active institutional control. EPA's 1985 standards assumed that active institutional controls (guarding or monitoring a site and remedial activities) will not be relied upon for more than 100 years after repository closure as the means to achieve acceptable waste isolation. The Energy Policy Act now asks this panel to advise EPA on the potential for post-closure oversight to prevent an unreasonable risk of breaching the repository's barriers or of causing unacceptable radiation doses to the public.

The advantage of relying on active institutional controls is the potential to reduce the near-term cost of achieving and demonstrating compliance with the environmental standards for Yucca Mountain. Some probabilistic projections, especially those involving human intrusion, will likely be contentious during a licensing review and substantial efforts may be needed to demonstrate acceptable repository performance. Societal practices such as monitoring drinking water quality could provide effective protection of populations near a repository, and credit for such practices could be beneficial in demonstrating repository safety.

The disadvantage of reliance on active controls is the history of loss of such controls which raises questions about the wisdom of relying on institutions to ensure repository safety. Historical examples of durable institutions generally involve functions that societies find useful (e.g., maintaining records), and it is difficult to project the willingness of future societies to perpetually monitor a repository site.

The NRC's regulations for geologic repositories have not assumed that active institutional controls would be effective in preventing human intrusion for more than 100 years after facility closure. This assumption appeared to be prudent for a HLW repository, since no practical method has ever been identified to guarantee that such active institutional controls will persist or will continue to be effective. "Passive" institutional controls, however, such as monuments, markers and land-use records, are likely to persist and be effective in deterring future human intrusion into a repository.

(5) Probabilistic standards. The cumulative release limits of EPA's 1985 standards applied to virtually all causes of releases, including human intrusion. Concerns about the scientific predictability of intrusion is reflected in the Energy Policy Act's identification of post-closure oversight and human intrusion as subjects for this panel's review. Predicting the probabilities of some rare geologic events, such as volcanic activity at Yucca Mountain, could prove nearly as troublesome as predictions of human intrusion. Therefore, I encourage this panel to include rare geologic events, along with human intrusion, when considering whether it is possible to make scientifically supportable predictions of potential repository disruptions.

In probabilistic risk assessments, the probability that an event will occur cannot always be determined from the historical frequency of occurrence of similar events. For rare events, the estimated probabilities are often values that represent an individual's degree of belief (grounded on some theoretical or empirical foundation) that the events will occur. Although such probability estimates might not be scientifically verifiable in the most rigorous sense, they have provided an adequate basis for past regulatory decisions (e.g., regarding seismic potential in the eastern United States). Thus, it is reasonable to expect that a probabilistic standard will prove workable during licensing. Nevertheless, some of the events of concern for predicting the performance of a repository may be even more speculative than events dealt with in the past, and could be difficult to evaluate during licensing. In the NRC staff's view, implementing probabilistic standards during repository licensing will be challenging, but should ultimately prove to be feasible.

(6) As low as reasonably achievable (ALARA). EPA's 1985 standards did not contain a specific requirement that projected releases be ALARA. EPA's containment requirements, which were derived from analyses of the waste isolation capabilities of hypothetical HLW repositories, were effectively "generic" ALARA levels. In contrast, an explicit ALARA requirement is a prominent feature of the recommendations of international advisory organizations.

The principal advantage of an explicit ALARA requirement would be consistency with other radiation protection standards. The disadvantage would be significant difficulties in evaluating compliance with such a criterion. The large uncertainties in projected repository performance would make any case-specific ALARA analysis highly speculative, especially if the performance of real or hypothetical alternative sites were to be considered.

The NRC staff would object to any broad-based requirement that repository releases be demonstrated to be ALAR , especially if suc ment were applied to site selection. The NRC's regulations now contain a requirement for consideration of alternatives to the major design features of a repository. Any more extensive ALARA analysis is likely to prove speculative and unworkable.

(7) 10,000-year period of concern. The containment requirements of EPA's 1985 standards applied only for the first 10,000 years after repository closure. In contrast, the recommendations of some international advisory groups and the regulations of some other nations are open-ended, restricting individual doses and risks in perpetuity. While not specifically addressed by the Energy Policy Act, questions have been raised about the time period for which environmental standards should be applied at Yucca Mountain.

The advantage of a 10,000-year cut-off can be stated very simply -- practicality. With a 10,000-year cut-off, the licensing process does not need to consider very speculative long-term geologic and climatic changes that might disrupt repository performance. On the other hand, some of the hazardous constituents of high-level waste have half-lives exceeding 10,000 years, and releases of those materials could pose a significant human health hazard well beyond 10,000 years. Previously, EPA reasoned that a repository that is able to meet its standards for the first 10,000 years after disposal would be likely to perform well for longer times, as well. It should be noted that, when EPA's standards were challenged in a Federal court, the court did find that EPA's explanation of its 10,000-year limit was adequate.

The NRC staff prefers that any numerical HLW standard be applied only for a limited time after disposal (e.g., 10,000 years). The further into the future one tries to predict repository performance, the more uncertain these predictions will be. In the NRC staff's view, the very large uncertainties inherent in estimating releases over very long times makes it impractical to make a scientifically rigorous demonstration of compliance with numerical regulatory limits. Instead, potential releases that might occur after the regulatory period should be estimated by DOE and disclosed in a suitable format, such as an Environmental Impact Statement.

## IV. CONCLUDING REMARKS

In conclusion, let me return to my earlier remarks about the basic Societal Pledge we are making to future generations. We are <u>not</u> promising to predict every nuance of future society's attitudes toward, or concerns about, radiological hazards. Nor are we trying to forecast the full range of potential changes in societal lifestyles and potential modes of exposure to releases from a repository. We are simply promising to provide future humans with the same type of radiological protection, and the same level of safety, that we would demand for ourselves. If this panel can focus its deliberations on determining the safety standards we would find acceptable today, I think reasonable and workable recommendations for HLW disposal standards can be developed. I wish you great success in your deliberations, and I offer you any support from the staff of the NRC that you might find helpful in your efforts.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE
WASHINGTON, D.C. 20555

June 7, 1996

The Honorable Shirley Ann Jackson
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Dear Chairman Jackson:

SUBJECT: TIME SPAN FOR COMPLIANCE OF THE PROPOSED HIGH-LEVEL WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

The purpose of this letter is to communicate the Advisory Committee on Nuclear Waste's (ACNW) observations and suggestions on the general principles for establishing the time span for compliance of nuclear waste facilities and our recommendations for specifying the regulatory time frame of compliance for the proposed geologic high-level waste (HLW) repository site at Yucca Mountain, Nevada. This letter follows up a letter from the ACNW dated February 9, 1996, on "Issues and [U.S. Nuclear Regulatory Commission] NRC Activities Associated with the National Research Council's Report, *Technical Bases for Yucca Mountain Standards*."

The time period for compliance of geologic HLW repositories is established at 10,000 years in the Environmental Protection Agency (EPA) standard 40 CFR Part 191 and the NRC regulation 10 CFR Part 60. Elements of the HLW standards and regulations were scrutinized by a National Research Council/National Academy of Sciences (NAS) Committee, which was prescribed by the Energy Policy Act of 1992. The findings of the NAS Committee are published in the *Technical Bases for Yucca Mountain Standards* (National Research Council, 1995). The NAS Committee concluded that there was no scientific justification or basis for specifying a truncation of the analyses at 10,000 years or at any other period of time. Instead, it recommended that the compliance evaluation be conducted to peak risk within the limits of the basic geologic stability of the Yucca Mountain region, which it suggested was on the order of a million years. In contrast to this recommendation, the ACNW has supported the 10,000-year time frame (e.g., letters to the Chairman of the NRC of June 27, 1991, and February 9, 1996). Nonetheless, in our most recent letter on this topic, the ACNW stated that further deliberations on the subject were appropriate. This letter reports on the results of our additional study. The ACNW will report to you in the near future on our recommendations on the time span for compliance of low-level nuclear waste facilities, building upon the

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principles identified and discussed in this letter. In addition, the ACNW plans to review the reference biosphere and critical group issues.

Our recommendations are derived from a working group meeting on "Regulatory Time of Compliance for Radioactive Waste Disposal" held during the 82nd meeting of the ACNW on March 27, 1996, and subsequent deliberations by the Committee. Three main topics were discussed at the working group meeting: (1) background and regulatory context for the existing HLW standard that specifies 10,000 years as a time frame for regulatory compliance, (2) insights on time of compliance from performance assessments for both high- and low-level nuclear waste, and (3) scientific/technical issues and concerns. During the working group meeting, presentations were made by personnel from the EPA; the Division of Waste Management, Office of Nuclear Materials Safety and Safeguards, NRC; the U.S. Department of Energy; the National Research Council staff; the Electric Power Research Institute; the Oak Ridge National Laboratory; as well as by individuals from private industry and academia. The latter individuals provided both national and international viewpoints on the problem of compliance time in regulations.

Background of the Problem

A necessary element of a standard or regulation that ensures the health and safety of the public is the compliance period -- the time that the risk of adverse consequences is below a specified level. This compliance period requires the integrity of the facility over the stipulated time interval. In the case of an HLW repository, the assessment of risk involves evaluation of the repository source term, including inventory and waste form; the performance of waste containers and engineered barriers; and the geological, hydrological, and climatological attributes of the site. If the risk of health effects is to be determined, this assessment also involves the specification of the biosphere and the critical population group in proximity to the repository.

In the existing generic standard for geologic HLW repositories, 40 CFR Part 191, EPA established a 10,000-year time of compliance at a distance of no more than 5 km from the boundary of the repository -- a time value that also was used in the NRC regulation. This time period has no scientific or technical justification but was based on an arbitrary compromise between conflicting desirable characteristics. Long time periods have attendant large uncertainties in the behavior of the geosphere and the biosphere, while short time periods have lower uncertainties but do not adequately address the time spans of some of the critical processes that cause release of radionuclides to the biosphere. This compromise was perhaps a justifiable approach for comparative evaluation of the multiple sites being considered when 40 CFR Part 191 was promulgated. Although not considered a compelling technical basis, this time period was roughly consistent with the period of glacial cycling and the potential profound impact of continental glaciation upon the geosphere and the biosphere. In providing a rationale for the 10,000-year time limit, the EPA stated, "This is not to say that times beyond 10,000 years are not important, but the Agency feels that a disposal system capable of meeting the proposed Containment Requirements for 10,000 years would continue to protect people and the environment well beyond 10,000 years." Although the standards of other nations differ in detail, the international community largely accepts the 10,000-year time frame, but also recognizes the need to evaluate site performance beyond the 10,000-year period, which constitutes a two-part approach.

In its appraisal of the technical bases for site-specific Yucca Mountain standards, the NAS Committee rejected the 10,000-year compliance period although it accepted that a transition to a glacial climate with its cooler, wetter seasons is probable during the next 10,000 years. Rather, the NAS Committee decided that long-lived radioisotopes derived from the repository might not reach the biosphere for more than 10,000 years, and thus it is important to evaluate the repository for a longer time interval. The NAS Committee chose to set this period of time at the predicted time of peak risk to the population as a result of leakage from the repository. It viewed this decision as requiring a period of time possibly extending into hundreds of thousands of years. In so doing, it did not accept the view espoused in the EPA and NRC standards and regulations that the uncertainties in predicting the repository performance at these periods are so large that the results are of questionable utility. The basis of the argument is that the subsurface environment at the repository horizon of Yucca Mountain is sufficiently stable that repository performance can be assessed with an acceptable uncertainty over a period of roughly one million years. The NAS Committee believes that inherent spatial uncertainties in interpolation of site characteristics, which are time independent, are a major contributor to assessment uncertainty.

The dilemma faced in developing the time span of compliance is that the period of time must be sufficiently long to include the evaluation of potential processes leading to the loss of the integrity of the repository and transport of radionuclides to the biosphere. Yet the time span should not be so long that the uncertainties in the process and events, and in the biosphere and critical population group, lead to meaningless results. In the case of a specific site, sufficient information should be available so that reasonable assumptions can be made in order that a defensible solution can be reached regarding the problem of a regulatory period of compliance. This approach is based on general principles and knowledge of the engineering and scientific aspects of the repository and its site.

*Considerations in Defining a Time of Regulatory Compliance*

After reviewing the basis for establishing a time of regulatory compliance, the ACNW has concluded that a series of premises and assumptions are a necessary foundation for the decision making process. These include general policy decisions that are generic and a range of scientific and technical considerations that are largely specific to the site and problem:

- The HLW repository system -- waste, containers, engineered barriers, and site geology -- must be capable of preventing leakage of radionuclides to the biosphere for a minimum period of time measured in several thousands of years.

- Risk evaluation is based on characterization of the repository site and investigations of the waste and its container and engineered barriers using performance assessment (PA). However, in the development of the regulations, the marked limitations in using PA as a predictive tool needs to be recognized. PA is primarily an investigative tool that can be used to distinguish between positive and negative attributes of the elements of the repository and, in the best of conditions, the relative range of risk under various assumed scenarios.

- The standard for a nuclear waste repository should be based on limiting risk to a critical group without the constraint of a prescribed time period of compliance. A time period should be defined in the regulations that implement the standard and should be prepared in concert with the characteristics of the waste, engineered barriers, and the nature and vagaries of the geosphere and the biosphere of a specific facility and site.

- The reference biosphere and the critical group that are used in assessing compliance should be defined in the regulations. These definitions are necessarily based on site characteristics and on the impact of climate and predicted climate modifications. They are related to predictions of the nature of society through time. Because of the great uncertainties in the latter, the ACNW recommends that the current societal state be used as the base scenario in predictions of the future states of society.

- Uncertainties in assessing future risks associated with the geologic/geographic setting and the repository design and related engineered features will increase with time. Factors that influence this increasing uncertainty include the following: geologic conditions and events that may disrupt the repository; climatic changes that could drastically increase the flux of water through the disposal system or change the regional hydrologic flow regime; degradation of the waste containers or repository materials; and synergistic effects of changing site conditions on the degradation of repository features. Design features can be implemented to preclude extreme variations in releases (e.g., waste forms, containers, and near-field barriers may be engineered to minimize transport out of the immediate repository facility and thus minimize uncertainties in transport for several thousand years).

## Regulatory Principles for Establishing the Time Span for Compliance

On the basis of the preceding considerations, the ACNW recommends that a two-part approach to definition of the compliance period be established for nuclear waste facilities. The first part involves the following three elements:

(1) The time period for compliance should be based on the estimated time for release and transport of the radionuclide contaminants to reach the critical group. This time estimate should be based on geologic, geochemical, and hydrologic characterization of the site and its environs, as well as regional study of geologic processes and their potential effects on the site, and total systems performance assessment. This estimate must confirm the ability of the repository system to retain radionuclides for a minimum of several thousand years. The selection of the time of compliance must be evaluated along with the specification of the reference biosphere and critical group.

(2) The reference biosphere and the lifestyles of the critical group should be defined on the premise that no major changes will occur in society that will significantly affect their lifestyles as they relate to risk from the repository and that the climate can be reasonably bounded. The minimum distance from the boundary of the repository to the critical group will be a major decision.

(3) The compliance time should be sufficiently short such that extrapolations of significant processes and their rates can be made robustly with reasonably modest uncertainties.

The second part of the compliance period regulations should be based on assessments extending from the specific compliance period to the calculated time of the peak risk to the critical group. There is no definitive measure of compliance in the sense of a numeric match between a standard and the calculated peak risk, and this second part should not be allowed to become a de facto regulation. A comparison between the standard used in the first part and the calculated peak risk should lead to identification of important performance factors that define risk to the critical group. Depending upon the extent to which the peak risk exceeds the standard, ameliorating actions to reduce this difference should be initiated, such as increasing the integrity of the engineered barriers, improving site characterization to more closely bound uncertainties, or, in the extreme, abandoning the candidate site.

## Scientific and Technical Insights Into the Time Span for Compliance of the Proposed Yucca Mountain Repository

Critical steps in the regulatory principles for establishing time of compliance as specified above in element (1) are the characterization of the proposed repository site and the relevant processes acting upon it and assessing the total system. Although site characterization is still in progress at Yucca Mountain, extensive data have been acquired and information has been derived from these data. The following scientific and technical insights that have been gained at the site over the past decade bear upon the definition of the compliance time in the forthcoming regulations designed specifically for Yucca Mountain.

- The current climate in the Yucca Mountain region is arid, with annual precipitation of roughly 15 cm. In the future, the climate will change, depending upon the relative importance of advancing cooler (glaciation) conditions and possible greenhouse effects that may counteract the cooling effect. Although the timing and precise amplitude of the climate change cannot be predicted, the range of conditions can be bounded in terms of timing and effect. Paleoclimatological studies in the region of Yucca Mountain suggest that during the last glacial period (14 to 20 thousand years ago) the precipitation may have been four times the present and the average annual temperature 10 °C cooler (Forester and Smith, 1995). Climatic conditions are anticipated to change, but the region is likely to be at least semiarid and will lie south of the glaciated area. Thus, it is unlikely that climate change will have a marked effect on the reference biosphere or the lifestyle of the critical group. Infiltration is likely to significantly increase as a result of the increased precipitation and cooler temperatures, but the total flux through the repository will still be limited. The maximum climatic change is not predictable with our present science, but all evidence from extrapolations indicates that the principal effect will occur prior to ca. 20,000 years.

- Results of recent site characterization activities at Yucca Mountain indicate that matrix, fracture, and fault infiltration are present in the unsaturated zone. Matrix flow results in long travel times, but fracture and fault flow that may lead to relatively rapid travel times also occurs. Ground water travel times within the saturated zone between Yucca Mountain and the location of the critical group, which is likely to reside in the Amargosa Valley several tens of kilometers south of the proposed repository, are poorly documented at this time. However, the low hydraulic gradient indicates that travel times are likely to be long. Further, the sorptive capacities of formations through which the water will traverse are not presently known and the degree of dilution of contaminants within the saturated zone has not been ascertained. In view of the likely long travel time of water in the saturated zone from the proposed Yucca Mountain repository to the critical group, the movement of contaminants may well take in excess of 10,000 years to reach the accessible environment, despite the potential for relatively short travel time through the fractures and faults of the unsaturated zone.

- The relative uncertainties in predicting the time dependent and spatial variations in the Yucca Mountain geosphere and related geologic processes have come to the forefront as a result of the NAS Committee's report and their statements on the confidence that can be placed on performance assessment at distant future times. The NAS Committee concluded that although ". . . the level of confidence for some predictions might decrease with time . . . [m]any of the uncertainties in parameters describing the geologic system are due not to temporal extrapolation, but rather to difficulties in spatial interpolation of site characteristics." The ACNW acknowledges that the spatial variations in the Yucca Mountain geosphere contribute to uncertainty. Nonetheless, we believe that with the completion of an adequate characterization of the site and with consideration of the integration over the heterogeneities for the operational scale of the pertinent processes, the time-dependent uncertainties in events and processes, such as climate change, will be more prominent than those derived from spatial variations. Yucca Mountain lies within a region of potentially high gradient tectonic and climatic processes. As a result, the ACNW anticipates that uncertainties will increase with time, although we agree with the National Research Council/NAS report that it should be possible to bound these uncertainties over a time span on the order of one million years.

Recommendations for a Yucca Mountain Repository Compliance Period

On the basis of the previous discussion of both generic principles and Yucca Mountain specific insights, the ACNW recommends the following two-part approach to establishing the ... period for compliance for the proposed HLW repository site at Yucca Mountain, Nevada:

The first part involves the following:

(A) The time period of compliance should not be specified in the risk-based standard for Yucca Mountain being prepared by the EPA. Rather, it should be defined in the regulations being developed by the NRC to implement the EPA standard and should use existing knowledge of the engineering and scientific aspects of this proposed repository and its environment.

(B) The time period should be defined in concert with specifying the reference biosphere and the critical group. The definition of the biosphere and the critical group should take advantage of known site characteristics and any other long-term effects that can be technically supported.

(C) The time span for the compliance period should be no shorter than an estimate of the anticipated time it takes for potential radionuclide contaminants to reach the nearest critical group and no longer than a time period over which scientific extrapolations can be convincingly made. Because of the need to come to closure on this subject, the ACNW suggests that the NMSS staff review the scientific and technical components needed to make these decisions, identify critical missing elements, and provide the necessary information in a timely manner. On the basis of currently available information, the ACNW anticipates that the appropriate compliance period will be somewhat greater than the present standard of 10,000 years. The increased distance from the proposed site to the nearest probable location of the critical group, the nature of the site and the likely characteristics of the waste, the containers, the engineered barriers, and the design of the repository, together with consideration of the stability of the site, suggest a time frame on the order of a few tens of thousands of years, but specifying a precise value must await more comprehensive assessments.

The second part of the compliance regulation should require assessment extending from the specified compliance period to the time of the calculated peak risk to the critical group. The regulation for compliance during this intervening period should be significantly less stringent than is used in the previous period, considering the increasing scientific, technical, and critical group uncertainties. Depending upon the extent to which the peak risk exceeds the standard for the first part, steps should be considered to ameliorate the potential risk. This second part of the compliance regulations should not be allowed to become the de facto regulation.

Summary

The regulatory time period for compliance is an important element in regulations for nuclear waste facilities and remains a problem in developing site-specific requirements for protecting the health and safety of the Nation, as well as its environment. The ACNW suggests a solution to this problem from a generic standpoint, which employs two parts. Using scientific and technical insights into the environment of the repository proposed for Yucca Mountain, we recommend an approach that establishes the time of compliance of the facility at this site, which differs from the current regulation and the proposal on this topic made by the National Research Council/NAS Committee in its report, *Technical Bases for Yucca Mountain Standards*. We believe that our recommendations will lead to a simple, robust, and defensible regulation that can be readily implemented.

Sincerely,

Paul W. Pomeroy
Chairman

References:

1. Report dated February 9, 1996 from Paul W. Pomeroy, Chairman, ACNW, to Shirley Ann Jackson, Chairman, NRC, Subject: Issues and NRC Activities Associated with the National Research Council's Report, "Technical Bases for Yucca Mountain Standards"

2. Report dated June 27, 1991, from Dade W. Moeller, Chairman, ACNW, to Kenneth M. Carr, Chairman, NRC, Subject: "Response to questions Accompanying Working Draft #3 of the EPA Standards"

3. R. M. Forester and A. J. Smith, "Late Glacial Climate Estimates for Southern Nevada: The Ostracode Fossil Record," in High-Level Radioactive Waste Management, Vol. 4, pp. 255- 2561, 1994

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

July 11, 1996

MEMORANDUM TO: Paul W. Pomeroy, Chairman
Advisory Committee on Nuclear Waste

FROM: James M. Taylor
Executive Director for Operations

SUBJECT: RESPONSE TO ADVISORY COMMITTEE ON NUCLEAR WASTE LETTER DATED JUNE 7, 1996, ON TIME SPAN FOR COMPLIANCE OF THE PROPOSED HIGH-LEVEL WASTE REPOSITORY AT YUCCA MOUNTAIN, NEVADA

I am responding to the June 7, 1996, letter from the Advisory Committee on Nuclear Waste (the Committee) to the Chairman. In that letter, the Committee provided observations and suggestions on general principles for establishing the time span for compliance of nuclear waste facilities. It also offered its recommendations for specifying the regulatory time span of compliance for the proposed geologic high-level waste (HLW) repository at Yucca Mountain, Nevada.

The Committee's comments on the general principles for establishing the time span for regulatory compliance are timely because, as you are aware, the staff is currently considering this topic in the areas of low-level waste (LLW) and HLW. As noted, the Committee was briefed on the broad outlines of the staff's approaches to defining regulatory time frames for LLW and HLW during its March working group on "Regulatory Time of Compliance for Radioactive Waste Disposal."

The Committee's letter and the observations, suggestions, and recommendations in it are directed toward the HLW geologic repository program. Therefore, this response will discuss only those staff activities in the HLW programmatic area. In this regard, it is apparent, from a comparison of the staff's presentation to the Committee and other proposed staff positions, and the Committee's recommendations, that there is general agreement on the principles and considerations for setting a time frame of regulatory compliance for a geologic repository. The staff supports a tiered approach (e.g., compliance with the regulatory limit up to 10,000 years and comparison with the regulatory limit as a goal beyond 10,000 years) which recognizes the difficulty in estimating repository performance over long time periods, but provides sufficient insight into long-term performance to assist licensing decisions (staff presentation to ACNW working group, March 27, 1996). This staff approach is similar in many ways to the Committee's two-part approach to definition of time frames for regulatory compliance in the HLW area. Finally, the staff also agrees that the exposure scenario (i.e., exposure pathway, reference biosphere, and critical group(s)) should be defined, to the extent possible, by rule.

As to the Committee's specific recommendations for defining a regulatory time frame for a HLW geologic repository, the staff will factor them into its ongoing activities. These ongoing activities take two forms -- interactions

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Enclosure 3

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with the U.S. Environmental Protection Agency (EPA) on EPA's site-specific standard and activities related to development of implementing regulations applicable to a repository at Yucca Mountain. The staff has previously informed the Committee of its continuing, regular interactions with EPA on EPA's site-specific HLW standard. It is now anticipated that EPA will issue its proposed Yucca Mountain standard in August of this year. It is the staff's intention to provide comments to EPA when the standard is published for public comment.

As noted in my response to the Committee's February 9, 1996, letter (J. Taylor to P. Pomeroy, dated March 8, 1996), the staff also is currently beginning to develop a strategy for the U.S. Nuclear Regulatory Commission's conforming rulemaking to implement EPA's Yucca Mountain-specific HLW standard. As part of that effort, the staff, in conjunction with the Center for Nuclear Waste Regulatory Analyses, recently has completed its preliminary technical analyses relevant to development of standards and regulations applicable to Yucca Mountain. These technical analyses and other ongoing studies will comprehensively address the Committee's suggestion that the staff review the scientific and technical components needed to define time frames for HLW disposal. Presently, the staff is using the results of these analyses and its existing knowledge of EPA's proposed standard to develop a strategy that will incorporate defensible approaches to address issues relating to time frame of compliance, definition of the exposure scenarios including critical group(s), reference biosphere, and the approach to incorporating the multiple barrier/defense-in-depth philosophy. The staff, therefore, welcomes both the Committee's existing recommendations on time frame for compliance for a HLW geologic repository and any future recommendations the Committee might draw from its recent session (June 25, 1996) on "Specification of Critical Group and Reference Biosphere." The staff expects to complete development of its strategy for implementing EPA's Yucca Mountain Standard in August 1996 and will keep the Committee apprised of the results of this effort.

Original signed by James M. Taylor

James M. Taylor
Executive Director
for Operations

cc: Chairman Jackson
Commissioner Rogers
Commissioner Dicus
SECY