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EPA Docket Center (EPA/DC)
Air and Radiation Docket
U.S. Environmental Protection Agency
EPA West, Mail Code 6102T
1200 Pennsylvania Ave, NW.
Washington, DC 20460

Attention: Docket ID No. OAR–2005–0083

To whom it may concern:

In response to EPA's Federal Register Notice of August 22, 2005 (Federal Register / Vol. 70, No. 161 / Monday, August 22, 2005 / Proposed Rules), enclosed please find the State of Nevada's formal comments on EPA's "Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada; Proposed Rule" (40 CFR Part 197).

After an exhaustive review process that encompassed EPA's proposed rule, as presented in the Federal Register Notice, as well as the reference materials cited in that Notice, Nevada concludes that EPA's proposed standard is inconsistent with the recommendations of the National Academy of Sciences (as required by the Energy Policy Act of 1992) and the July 9, 2004 ruling of the U.S. Circuit Court of Appeals for the District of Columbia. Not only is the proposed rule illegal, but it stands in stark opposition to three decades of environmental regulatory practice, contradicting EPA's own historical approach to public health and environmental protection and setting a disturbing and dangerous precedent for future regulation of radiological and hazardous materials.

Nevada concludes that EPA has no alternative but to withdraw the proposed rule and reissue a new draft standard that abandons the arbitrary and scientifically unjustified bifurcated radiation exposure limits; that continues strict groundwater protection requirements through the period of maximum exposure; that eliminates statistical gerrymandering through the use of median vs. mean calculations; that removes inappropriate and illegal intrusions into the NRC regulatory arena; and that returns to EPA's historical approach to radiation and environmental protection.

The only scientifically and legally supportable way to bring EPA's Yucca Mountain rule into compliance with the Court's directives and the NAS recommendations is to extend the 15millirem per year maximum exposure threshold, together with the 4 millirem groundwater protection requirement, through the period of maximum projected releases for the Yucca Mountain facility. This simple and straight-forward approach is the one Nevada recommended to EPA even before the current proposed standards was released. It remains the ONLY possible course of action that can result in a legally, scientifically and morally defensible radiation health protection regime for the proposed Yucca Mountain facility.

Sincerely,

Robert R. Loux
Executive Director

RRL/cs
Enclosures
cc Nevada Congressional Delegation
U.S. Nuclear Waste Technical Review Board
U.S. Advisory Committee on Nuclear Waste
Samuel Bodman, Secretary of Energy
David R. Hill, General Counsel, U.S. Department of Energy
Dr. Ralph J. Cicerone, President, National Academy of Sciences
Dr. Lars-Erik Holm, Chairman, International Commission on Radiation Protection
National Conference of Radiation Control Directors
National Council on Radiation Protection and Measurements

COMMENTS BY THE STATE OF NEVADA ON EPA's PROPOSED NEW RADIATION PROTECTION RULE FOR THE YUCCA MOUNTAIN NUCLEAR WASTE REPOSITORY

November 2005

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(Appendices H and I are DVD's which will be submitted via Federal Express.)

I. Executive Summary

A. Overview of Proposed Rule

On August 9, 2005, the Environmental Protection Agency ("EPA") announced a second proposed rule setting forth the primary radiation protection standard to be used in evaluating the safety of the proposed Yucca Mountain nuclear waste repository in Nevada ("Yucca."). The new proposal, published on August 22, 2005, emerges as EPA's misguided attempt to respond to a 2004 court ruling that had invalidated the Agency's first Yucca radiation protection rule. 70 Fed. Reg. 49014.

In *Nuclear Energy Institute, Inc. v. EPA,* 373 F.3d 1251 (D.C. Cir. 2004) ("*NEI*"), the Court of Appeals for the D.C. Circuit (the "Court") vacated both the original EPA Yucca rule and the corresponding Nuclear Regulatory Commission ("NRC" or “Commission”) radiation protection standard. The Court found that these rules, which terminated their compliance periods after 10,000 years, (a) were not “based upon and consistent with” recommendations of the National Academy of Sciences ("NAS" or “Academy”), as Congress required in the Energy Policy Act of 1992 (“EnPA”); and (b) did not protect against the anticipated peak radiation risks that are expected from the repository after man-made waste packages fail.

Just one day after the EPA announced its new rule, and in lockstep with the Department of Energy ("DOE") and EPA, NRC Staff on August 10 recommended to the Commission that NRC adopt as its new radiation protection rule for the licensing of Yucca an almost identical version of the proposed new EPA rule. On August 30, the Commission approved in a Staff Requirements Memorandum the same proposed NRC rule that its staff had recommended. SRM on SECY-05-0144 (Aug. 30, 2005).

The new standard proposed by EPA and NRC is nearly identical to the previous one. It suffers from virtually the same legal and scientific defects (and more) as the standard rejected by the Court and the Academy. The old rule established a 15 millirem/year individual protection standard for the first 10,000 years, and no limit thereafter. The new rule establishes the same 15 millirem/year standard for the first 10,000 years, and an extremely (and unprecedentedly) high 350 millirem/year standard thereafter. The old rule included no groundwater protection standard after 10,000 years, and that remains true for the new rule.

The disparity between the radiation dose limits before and after 10,000 years actually becomes far greater than the 23-fold difference between 15 and 350. That is because the *method* EPA directs for determining compliance with the "350" sharply diverges from that used for determining compliance with the "15," making the 350 millirem/year standard the functional equivalent of a much higher number, one so high that it affords essentially no public protection at all. EPA’s new rule is not even health-based, as the law requires, because EPA’s new compliance method would approve of the Yucca repository without regard for many of the actual radiation doses persons will suffer from it.

DOE can only predict long-term repository performance from the results of numerous computer simulations. Because these simulations produce different projections of dose rates in the accessible environment over long periods, DOE must use a statistical measure to summarize the disparate results. Under the proposed rule, the projected radiation doses before 10,000 years would be evaluated against the 15 millirem/year limit using the *mean* results of these various performance predictions, as NAS explicitly recommended. Yet, contrary to the NAS's recommendation, the doses after 10,000 years would be evaluated against the 350 millirem/year limit under a different statistical measure, using the *median* results of the performance predictions. This is no small variance. Because the median of DOE's Yucca performance predictions is nearly three times lower than the mean, the new median standard equates to 1000 millirem/year in mean-equivalent terms, or *70 times less stringent* than the 15 millirem/year standard EPA has for decades defended as appropriate to protect human health.

EPA's new rule would impose on future generations the laxest radiation protection standard in the world for a nuclear waste repository. The long-term individual protection standard would permit doses far higher than those EPA has consistently, until now, recognized as damaging to public health. The dose permitted at Yucca would be roughly *ten times* greater than what EPA, NRC and other regulatory bodies have previously allowed for *all* non-medical anthropogenic radiation sources combined.

EPA claims its new standard will provide adequate protection because its nominal second-tier limit would extend out to one million years. But the risks of EPA's lax second-tier standard are in fact not temporally distant ones, as EPA implies. In addition to providing essentially no protection for the long period after 10,000 years, EPA's new rule also *provides essentially no protection for the period before 10,000 years either.* This is because the timing of the predicted peak dose is simply an artifact of DOE's computer modeling runs. These runs depend entirely on DOE's optimistic predictions that its "miracle metal" waste containers, which have been tested only for short periods in laboratories, will not corrode in the hot, relatively humid, acidic repository environment at Yucca until after 10,000 years.

If that key assumption proves wrong, as EPA recognizes is possible, the peak may occur much earlier. But there is no backup in that case, because the rule lacks any requirement for "defense in depth," the *sine qua non* of nuclear safety and a principle both EPA and NRC claim to support. Defense in depth is necessary because once a repository is created, its impacts cannot be undone by future corrective actions. Thus, if Yucca is designed and licensed based upon a lax long-term dose limit of 350 millirem/year (1000 millirem/year mean-equivalent), people in thousands or even hundreds of years may be exposed to these or much higher levels of radiation. This regulatory failure becomes not just a problem for societies hundreds of thousands of years from now; it becomes an immediate problem for our great-grandchildren and their children.

While the proposed rule is indefensible from any standpoint of public health protection, it makes perfect sense in one respect: DOE's performance models suggest that once its Yucca waste packages fail, a median peak dose of around 300 millirem/year is likely. Not coincidentally, EPA proposes a standard just lax enough to narrowly "pass" the repository for an NRC construction permit, despite long-term radiation releases that would fail any other domestic or international public health standard. As with its prior rule, EPA has ignored the risk to life and health from radiation leakage from the proposed DOE repository and has tailored the licensing standard to fit comfortably above DOE's performance projections.

Somewhere along the way, EPA came to believe that its job was to facilitate the licensing of Yucca Mountain rather than to objectively evaluate its safety to human beings and the environment. Everything about the new EPA rule places expediency above public responsibility, and cynicism above science and the law.

B. Key Concerns with the Proposed Rule

EPA's new rule has numerous fatal defects. Among other things, and as explained further below, the proposed rule has the following problems:

- ***Failure to Adopt NAS's Peak Dose Recommendation.*** As the Court emphasized, NAS could hardly have been clearer that EPA's public health standard should remain in effect through the period of peak dose, and that no scientific basis exists to curtail that standard at 10,000 years. Like the old rule, the new one abruptly abandons EPA's health-based dose standard after 10,000 years with no scientific justification. The substitution of a second-tier standard 70 times less stringent, without scientific support, is an obvious effort to circumvent the "peak dose" approach referenced by the NAS and the Court, so as to "pass" the repository. In short, EPA has simply replaced an infinite dose standard, which cannot be violated as a matter of theory, with an extremely lax standard which (it thinks) cannot be violated in practice. In neither case will the standard provide any satisfactory test of geologic isolation.

- ***Failure to Adopt NAS's Statistical Measure Recommendation.*** Contrary to NAS's specific recommendation, the rule permits repository designers to design Yucca based on the anticipated *median* results of DOE's post-10,000-year performance analyses, rather than the *mean* results (or "expected values") of those analyses. This is directly contrary to the NAS's recommendation that the mean be used, and is unsound from the standpoint of elementary statistical science and mathematics.

- ***Failure to Adopt the NAS's Exposure Recommendations***. The level of human exposure after 10,000 years permitted by the new rule far exceeds 2 to 20 millirem/year, which EPA previously recognized as the NAS's recommended acceptable range of radiation exposure. Until now, EPA has expressly adhered to that range. But EPA's proposed rule would exceed that range by a factor of between 17 (for the median) and 52 (for the mean), taking the high end of the recommendation. The new higher level, allowing a large number of additional cancer deaths over time, violates EnPA and the clear instructions of the Court.

• ***Violation of EPA's Own Public Health Protection Standards.*** In its prior Yucca Mountain rulemaking, EPA expressly rejected a two-tier regulatory approach applying a 150-millirem standard past 10,000 years, finding that neither EPA nor any other regulatory body would consider such a limit acceptable. EPA also rejected proposed standards of 70 millirem/year and even 25 millirem/year as providing insufficient protection of public health. EPA now does an about-face with no rational justification. Its new standard is so weak and inconsistent with long established national concepts of radiation protection that the President of the prestigious National Council on Radiation Protection has publicly opposed it.

• ***Weakest Standard in the World.*** EPA's proposed radiation protection standard would be the weakest peak dose standard applied anywhere in the world. It exceeds the maximum acceptable radiation exposure from man-made sources in all industrialized countries, and the proposed cleanup standard for other DOE sites with radioactive waste, roughly by a factor of 10.

• ***Abandonment of NAS and International Consensus on Apportionment.*** The NAS Report, OAR-2005-0083-0076 (hereinafter the "NAS Report"), identifies a "general consensus" among national and international bodies on a framework for public health protection from radiation releases. EPA has until now joined in this consensus, limiting to100 millirem/year the amount allowed for continuous or frequent exposures from all non-medical anthropogenic radiation sources. The fraction of that total typically allocated to high-level waste disposal is 10 to 30 millirem/year. In flagrant violation of this apportionment principle, the proposed rule would allow a single source to far exceed the amount that could safely come from all sources. EPA discards its past positions without any rational justification.

• ***Abandonment of Groundwater Protection.*** The new standard would abandon any groundwater protection standard just after 10,000 years, arbitrarily eliminating this protection in the very manner criticized by the Court. Ironically, EPA successfully defended in Court (against a challenge by the Nuclear Energy Institute) the application of a separate groundwater standard for the repository. Now, it arbitrarily abandons that very standard after 10,000 years.

• ***Misinterpretation of the Importance of Uncertainty.*** The centerpiece of EPA's rule defense—an appeal to "uncertainty"—is untenable on multiple levels, and provides no foundation for the proposed rule. Uncertainties in the Yucca Mountain setting do not increase materially after 10,000 years. Moreover, even if there were a substantial increase in uncertainty, EPA fails to explain rationally how this would justify a looser standard rather than a conservative, protective one that applies through peak dose. EPA's use of the term "uncertainty" is chronically vague and fails to acknowledge that all of Yucca's uncertainties support a *more protective* rather than a loosened standard. Once again, EPA has departed from past positions with no rational reason. Moreover, EPA's assertions about uncertainty largely recycle positions that were already considered and rejected by NAS and the Court.

- ***Rejection of Conservative Analysis.*** EPA fails to provide any rational grounds to support its puzzling notion that a perceived over-conservatism in DOE's computer modeling somehow supports adoption of a lax radiation standard. There is no scientific basis for the proposition that conservatisms will necessarily increase after 10,000 years; in fact, the opposite is just as likely, or more likely. Moreover, to the extent conservatisms are unavoidable because of a lack of scientific knowledge, the rule never explains why EPA's traditional use of conservatism or bounding assumptions in the face of uncertainty would not be more appropriate. And information from EPA's key source on uncertainty, the Cohen report, confirms that, far from being conservative, DOE's modeling contains enormously optimistic assumptions about repository performance, particularly on the issue of corrosion of DOE's waste packages.

- ***Certain Collapse of the Rule***. EPA bases its selection of 350 millirem/year on its conclusions about uncertainty and conservatism after 10,000 years. These conclusions are based on DOE's analyses that are relatively old and undergoing reevaluation. EPA fails to account for the likelihood that the analyses that DOE will use in its license application, or the analyses that NRC will rely on in its licensing decision, will be dramatically different from the ones relied on in the proposed rule. To the extent these are different, the essential premises for the EPA rule will disappear, with the result that the 350 millirem standard cannot possibly apply. At the very least, EPA must provide that its 15 millirem standard for the pre-10,000 year period will continue to apply in the post 10,000-year period if the pre- and post-10,000 year period performance assessments DOE uses in its application (or the ones used by the NRC in its licensing decision) exhibit essentially the same amounts of uncertainty or conservatism.

- ***Misuse of Natural Background***. The proposed rule offers a spurious analogy to natural background radiation levels that is inconsistent with EPA's past practice, and is also predicated on a series of unsupported assumptions, including a misunderstanding of the role of radon in natural background radiation and an arbitrary selection of Colorado as a benchmark for comparison. In the past, EPA and other national and international radiation standard setting organizations have rejected such comparisons in defining acceptable levels of risk, and EPA offers no rational explanation for its change in position. Moreover, even if natural background or natural background variations were somehow considered relevant, EPA cannot explain how they are uniquely relevant to the post-10,000 year period.

- ***Abandonment of Intergenerational Equity***. The new standard wrongly assumes it is ethically permissible, and consistent with EPA's duty to protect public health, to expose future generations to radiation levels far higher than we would tolerate today. EPA even attempts to fashion a "minimal" principle of intergenerational justice from sources that would offer a far higher regard to future generations than does the proposed rule. This is contrary to prior EPA positions without rational explanation, violates national policy expressed in NEPA, and violates an international convention on high-level radioactive waste disposal to which the United States is a party.

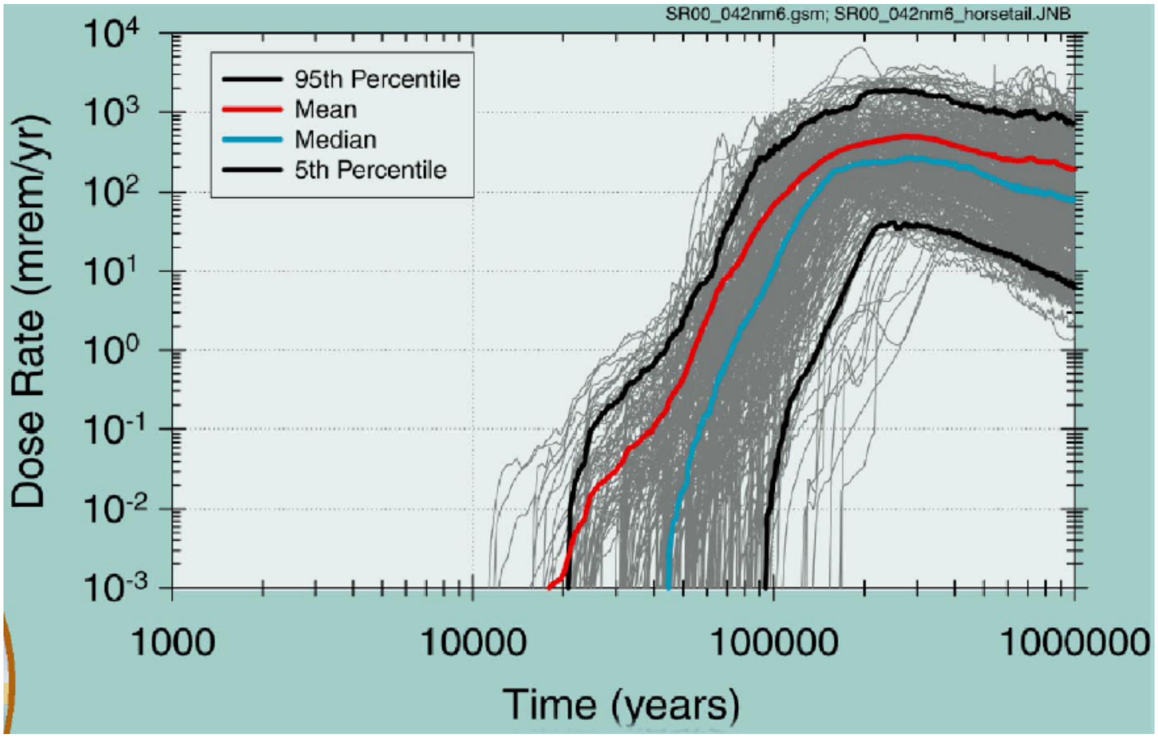
- ***Untenable Modeling Constraints***. EPA proposes a series of modeling constraints that themselves violate NAS's recommendations. These constraints (arbitrary limitations on the NRC's selection of FEPs, or "features, events, and processes") also contain unexplained categorical exclusions and cannot be squared with sound science. Moreover, the effect of these constraints (especially the one limiting future climate states) is to eliminate the very uncertainties EPA uses to justify 350 millirem/year, making EPA's rule internally inconsistent.

- ***Actions in Excess of Statutory Authority.*** EPA's proposed rule would exceed the agency's lawful authority, intruding into DOE's role of preparing a licensing application and the NRC's role of resolving adjudicatory facts and making a licensing decision. Lacking statutory authority, EPA also proposes unlawfully to delegate part of its own rulemaking authority to the NRC.

- ***Violation of the Information Quality Act.*** EPA's proposed rule relies almost entirely on a single "scientific" study prepared by a consulting firm. That study was never subjected to peer review, in clear violation of the Information Quality Act**.** It is an unabashed repository advocacy piece riddled with errors and biases.

C. A Picture Worth 10,000 Words: Fitting the Standard to Yucca's Inferior Geology

The figure below, summarizing DOE's numerous performance projections for the Yucca repository, shows projected peak radiation doses from Yucca as a function of time, assuming DOE is correct in its optimistic assumption that its waste containers will last for at least 10,000 years. Nevada has added curves showing the mean and the median results of the performance runs over time. This figure is adapted from the Figure 12.1 of EPA's Cohen Report, which reproduced it from DOE's SSPA, Volume 2, Figure 3.1.2-1.



The figure illustrates several key points:

- **EPA has constructed its standard to fit the projected dose curves.** The standard is stringent when DOE assumes, based on optimistic projections of waste container longevity, that no releases will occur (those assumptions explain the non-existence of projected doses during the first 10,000 years). It is lax when DOE assumes a higher degree of threat.

- **There is no apparent large increase in uncertainty after the time of peak dose, as measured by the distance between the 95% and 5% curves**. The large uncertainty prior to the peak dose is the uncertainty associated with the projected time of waste container failures.

- **The selection of the median is outcome-determinative.** At peak dose, the mean is approximately three times greater than the median (note that the scale of the Y axis is logarithmic), and is well above even a lax 350 millirem/year standard.

- **The standard would impose an enormous intergenerational burden.** After peak dose occurs, mean and median dose levels decline only gradually for the next 800,000 years (again, note that the scale of the X axis also is logarithmic). This is because radioactive contamination continues to leak from the site over a very long period. Thus, for hundreds of thousands of years—a period more than two orders of magnitude greater than the entire history of human civilization—dose levels will remain close to peak dose. However, the benefits—if there are any—would only be realized by current generations.

- **If DOE is wrong about its waste containers, the 15 millirem/year standard will be grossly exceeded well before 10,000 years.** The figure illustrates that, if the waste containers fail in the first thousand years, dose rates will exceed 15 millirem/year and rise rapidly to mean levels of approximately 1000 millirem/year within 10,000 years. If waste containers fail in 200 years or less, as Nevada's eminent corrosion experts believe will happen, the human population will not have to wait for hundreds of generations to witness overexposures. Such overexposures will occur much sooner.

II. Explanation of the Rule's Function

To appreciate the importance of the rule proposed by EPA, and the implications of its many flaws, some understanding of how this rule will function is helpful.

To obtain a license for Yucca Mountain, DOE will have to use computer *simulations* and *predictions* to demonstrate, to the satisfaction of NRC, that its repository will likely comply with the standard EPA sets. Those computer simulations will be based on mathematical models, assumptions, and, sometimes where data is lacking, on "expert elicitation." If the simulations produce a reasonable prediction of compliance, NRC may assume that reality will correspond to the simulations and will grant DOE a license to construct the repository. It is essential that the standard, and the related NRC compliance determination, be sufficient to distinguish a safe repository from an unsafe one. To do this it is required that the standard and compliance regime be sufficiently robust to test the sufficiency of all of the proposed engineering and natural barriers.

DOE will not, however, be able to take future actions to actually guarantee compliance with EPA's safety standards. Because Yucca Mountain's wastes will remain lethal for, and likely outlast the Department of Energy by, millennia, and because those wastes will be buried deep within the ground, in an irretrievable fashion, DOE cannot guarantee that it or anyone else will always be able to monitor the site or take protective measures to ensure that EPA's dose limit is not exceeded. In fact, the NAS specifically rejected basing Yucca standards on assumptions about future generations' abilities to monitor the site and to take additional protective actions. And while future societies' behavior is inherently unknowable, the societies that suffer the brunt of Yucca Mountain's risks also may have no ability to impose their own engineering controls or safety standards on the waste. Indeed, because the site will be concealed deep beneath the ground, they may suffer the consequences of its failure without even knowing that it exists. If the site fails, these future generations probably will be able to do little or nothing about it.

EPA's standard thus will apply only to, and have importance only for, DOE's application for licensing. Once the license is granted, and (as planned) the site is closed and the option to retrieve the waste is gone, the EPA standard for all practical purposes ceases to exist. For that reason, the integrity of that standard, and of the licensing process, is of crucial importance. The standard and the licensing process provide potentially the only opportunity to ensure the safety of future generations. If EPA's standard is too lax, those future generations will have no remedy against the consequences of EPA's abdication of its protective role. Likewise, if EPA unlawfully tinkers with the licensing process, pre-setting assumptions and attempting to rig the outcome, the government's only opportunity to ensure that Yucca Mountain is safe will be lost.

III. <u>Legal Context of the Proposed Rule</u>

When it rejected EPA's previous compliance period, the Court understood that in ordering EPA to comply with the EnPA requirement that its rule be "based upon and consistent with" the NAS recommendations, it was not merely addressing a minor oversight. Instead, the Court enforced an important statutory responsibility grounded in the protection of public health and safety. As the Court noted, "[I]t was Congress that required EPA to rely on NAS's expert scientific judgment, and given the serious risks nuclear waste disposal poses for the health and welfare of the American people, it is up to Congress—not EPA and not this Court—to authorize departures from the prevailing statutory scheme." *NEI*, 373 F.3d at 1273.

As the Court recognized, that statutory scheme places limits upon EPA's discretion. Although EnPA affords the EPA administrator discretion "in the exercise of his authority related to public health and safety issues," *id*., it provides no authority to establish standards that contravene NAS recommendations, or that betray EPA's fundamental statutory responsibility to devise Yucca standards that are protective of public health and safety. As EPA has earlier described the scope of its discretion, it is bound to "reach final determinations that are congruent with NAS analysis" whenever it can do so "without departing from the Congressional delegation of authority to promulgate, by rule, health and safety standards for the protection of the public." Background Information Document for 40 CFR 197, at ES-5.

EPA therefore must not treat compliance with the Court of Appeals' ruling and the NAS's recommendations simply as a matter of technical correction, by providing a nominal standard that fails to discharge EPA's fundamental obligation to set a Yucca radiation standard protecting the public from near and long-term radiation risks. Yet this is what EPA proposes to do. Nevada is alarmed by the lack of seriousness with which EPA apparently views this obligation, exemplified by its continued questioning of a "regulatory emphasis" on a peak dose standard, and its insistence that DOE's performance assessments will not even need to be "alter[ed]" or "changed fundamentally" to meet the new compliance period.

IV. <u>Nevada's Proposal to EPA</u>

On February 3, 2005, Nevada submitted formal but preliminary comments to EPA on a revised standard for Yucca. Nevada concluded that there was no logical, scientific, or legal reason why EPA could not and should not extend the 15 millirem/year radiation protection standard out to the time of peak dose from the repository, whenever that may occur. Nevada emphasized this approach in a face-to-face meeting with EPA officials on April 29, 2005. But Elizabeth Cotsworth, Director of EPA's Office of Radiation and Indoor Air (the office with cognizance over the new rule) candidly informed Nevada that its approach was the only one EPA was *not* considering, because it would result in a standard that was "not implementable," meaning of course that Yucca could not meet it.

V. Abbreviated Comment Period

Although Nevada appreciates that EPA extended the proposed 60-day public comment period to 90 days, Nevada continues to object to the short period afforded to the public to comment on this very complex proposed rule, with its equally complex and lengthy referenced sources. During the original Part 197 rulemaking proceeding, the public was given 180 days to comment. Nevada and its Congressional Delegation on several occasions formally requested at least 180 days for commenting on the proposed new rule, especially in view of the numerous and profoundly important issues it raises. Moreover, the license application has been substantially delayed and so affording additional time would not have affected DOE.

Problems with EPA's 350-Millirem Standard

VI. EPA's Two-Tiered Standard is Unlawful and Arbitrary

A. This Two-Tiered Approach Fails to Conform to the Court Decision and the NAS Report

Like its predecessor, EPA's proposed rule would after 10,000 years terminate its only radiation standard that protects public health. The only innovation in EPA's new approach is to propose a nominal second-tier standard, 70 times weaker in mean-equivalent terms, for the longer-term period in which all of DOE's modeling runs show leakage from the repository. That approach again abrogates the central point of the NAS and the Court: that the repository should safeguard citizens *at the time of the peak dose* that will occur from repository leakage, whenever that occurs. See *NEI*, 373 F.3d at 1273 ("NAS recommended that *the compliance period extend to the time of peak risk.*") (Emphasis added). Most importantly, EPA does not and cannot show that its standard will result in a safe geologic repository at Yucca Mountain.

So resistant is EPA to the straightforward peak dose requirement addressed by the NAS and the Court that the proposed rule even states that "[w]e do not want to place more regulatory emphasis on peak dose projections than can be justified." 70 Fed. Reg. 49030. EPA recognizes in its proposed rule that simply extending its 15 millirem/year standard to cover the period of peak dose "would be straightforward in responding to the Court decision," 70 Fed. Reg. 49032, and that its retention of a protective first-tier standard "might appear inconsistent" with a proposal that would allow peak doses shortly after that tier ends which far exceed 15 millirem/year. *Id.*

EPA's two-tier approach rests upon a severely crabbed reading of the Court of Appeals' ruling and the NAS recommendations, positing that as long as a standard is in place through the time of peak dose, it is irrelevant if that standard drastically exceeds that which NAS and EPA until now have recognized as protective of public health. That cynical reading cannot be reconciled with the text and context of the Court's ruling and the NAS recommendations. The Court cited multiple references in the NAS report calling for "the standard" to extend to the time of peak risk. *NEI*, 373 F.3d at 1271-73 (citing NAS Report at 2, 55-56, 119); *id.* at 1270 (NAS "unequivocally recommended a standard pegged to the time when radiation doses reach their peak").

The most natural and common-sense reading of these references is the "straightforward" one considered and then summarily rejected in the proposed rule: to extend the health-protective standard that EPA has already identified, consistent with NAS recommendations on risk levels, so that it clearly applies through peak dose. These references provide no support for the notion that merely providing a number through peak dose, even if it is far less stringent than the risk levels that NAS and EPA have previously deemed acceptable, can be "consistent with" NAS's approach and meet EPA's legal responsibility and duty to protect the public. For example:

- NAS clearly recommended that compliance with "*the standard*" be measured "at the time of peak risk, *whenever it occurs*." NAS Report at 2 (emphasis added). Rather than suggesting any relaxation of the standard after 10,000 years, NAS only qualified the statement by noting that the occurrence needed to be "[w]ithin the limits imposed by the long-term geologic environment, which is on the order of one million years." NAS Report at 2.

- NAS's recommendation on the time frame of "the standard" was "based upon performance calculations provided to us," in which it "appears that peak risks might occur tens to hundreds of thousands of years into the future." NAS Report at 2, 119.

- NAS noted that a "general consensus exists among national and international bodies on a framework for protecting public health," placing a limit of 100 millirems per year on continuous or frequent exposures from *all* anthropogenic non-medical radiation sources. *Id.* at 4. Following this apportionment principle, this consensus would assign to high-level waste disposal only 10 to 30 millirem per year. *Id.* at 4.

- NAS provided EPA with a range of acceptable risk levels and dose limits intended to provide a "reasonable starting point for EPA's rulemaking." NAS Report at 5. The acceptable range of radiation exposure recommended by NAS extends from 2 to 20 millirems per year. EPA has already construed these levels as part of the "findings and recommendations of the NAS" within the meaning of EnPA, and has already rejected a proposed standard of 25 millirems per year as "above the upper limit recommended by the NAS." Response to Comments at 4-5.

• NAS's rejection of a 10,000-year threshold as having "no scientific basis" reflected its serious concern that limiting the standard in this manner might be "inconsistent with protection of public health."

• NAS particularly warned against calculational approaches that "may seem to simplify licensing," but could not support a finding that there be "no unreasonable risk to the public." NAS Report at 55.

EPA is apparently aware that in the proposed rule, the true compliance period effectively ends at 10,000 years. In its discussion of deteriorating repository performance, the proposed rule notes that "[i]f such a dramatic deterioration were projected to occur *close to the regulatory time period* it would be a more pressing concern for licensing decisions than if it were to occur many hundreds of thousands of years into the future (remembering that the uncertainty in performance projections increases with time)." 70 Fed. Reg. at 49028 (emphasis added). The reference to the "regulatory time period" in this sentence, contrasted with a point of time hundreds of thousands of years in the future, would be incomprehensible if EPA believed that the real compliance period extended through the period of peak dose.

In short, a rule that terminates the health-protective standard at 10,000 years despite the absence of any scientific basis, and thereafter applies a standard dramatically exceeding all established norms for radiation exposure, using a compliance method that ignores many exposures that are even greater, cannot possibly qualify as "based upon and consistent with" NAS's peak dose recommendation. Nevada is mindful that EPA, in its proposed rule, has attempted to construe the NAS recommendations as a "starting point," and to portray its proposed rule as a reasonable modification based upon policy grounds. But while the Court recognized EPA had "some flexibility" to craft standards in light of NAS's findings, it warned that "EPA may not stretch this flexibility to cover standards that are *inconsistent* with the NAS Report." *NEI*, 373 F.3d at 1273.

The proposed rule has done precisely that. Like its predecessor, it resembles *Natural Resources Defense Counsel v. Daley*, 209 F.3d 747, 754 (D.C. Cir. 2000), quoted in *NEI* for its rejection of the conclusion that a measure four times as likely to fail as succeed could show compliance with the law. Only in a world in which "'based upon' means 'in disregard of' and 'consistent with' means 'inconsistent with'", *NEI*, 373 F.3d at 1272, could a rule allowing long-term radiation levels to exceed EPA's health-based standard by orders of magnitude, and continuing to terminate the protective standard at the same arbitrary point in time, be construed as "based upon and consistent with" the NAS's peak dose recommendation.

B. <u>The Two-Tiered Approach Contradicts EPA's Own Decisive Rejection of Similar Standards on Public Health Grounds</u>

The proposed rule is the latest and perhaps least protective version of an approach that EPA soundly rejected in its previous rulemaking as incompatible with well-established public health and safety standards. In its June 2001 Response to Comments document addressing its previous iteration of Part 197, EPA thoroughly rejected a suggestion that it should consider gradually relaxing its Yucca Mountain radiation standard over the progression of time. The commenter making this suggestion had proposed allowing the 15 millirem/year standard to increase to 150 millirem/year from 10,000 to 100,000 years, and to 1.5 rem/year from 100,000 to 1 million years. EPA rejected this proposal as "flawed," offering the observation that "[n]o regulatory body that we are aware of considers doses of 150 mrem to be acceptable, much less 1.5 rem, for members of the general public." Responses to Comments at 3-8.

In its previous Yucca rulemaking, EPA vigorously defended 15 millirem/year as the appropriate public health and safety standard, rejecting additional suggestions that the standard could be relaxed to 70 millirem/year or even 25 millirem/year. EPA emphasized that "EnPA instructed us to write standards 'based upon and consistent with' the findings of NAS. The annual risk basis of the 15 mrem limit…is within the range of annual risk levels which NAS suggested." Responses to Comments at 4-5 (citing NAS Report at 5). A key part of EPA's rationale was therefore to conform its standards to risk levels suggested by NAS, corresponding to a range between 2 and 20 millirem/year. In its final rule, EPA observed that its adoption of the 15 millirem/year standard was based in part on the NAS Report, noting also that "[t]his level is 15% of the ICRP-recommended total dose limit. It falls within the range of standards used in other counties and the range recommended by NAS, and is also consistent with the individual-protection requirement in 40 CFR part 191." 66 Fed. Reg. at 32088 (June 13, 2001).

In its defense of the 15 millirem/year standard, EPA disagreed "particularly strongly" with a commenter who recommended a 70 millirem/year standard as "adequately protective," noting that the risk level associated with that standard "is about five times as high as the risk level associated with the individual protection limit. This is well above the NAS recommended level and unprecedented in the current regulations of this and other nations for this activity." Responses to Comment at 4-5, 6. EPA noted that a 70 millirem/year standard would result in "a risk level at Yucca Mountain that is significantly higher than any facility that falls under 40 CFR part 191, such as WIPP and future radioactive waste disposal facilities"; and would violate well-established norms of apportionment, because "70 mrem from one source is too high a proportion of the annual100 millirem recommended by NCRP and ICRP (excluding background, occupational, accidental, and medical sources)." *Id*. at 4-5. On similar grounds, EPA even rejected several suggestions for a 25 millirem/year standard, concluding that even that level would be "higher than that recommended by the NAS." *Id.*

The proposed rule fails entirely to support EPA's dramatic retreat from the consensus position of NAS and other regulatory and advisory bodies, including EPA's express rejection of a similar two-tier standard. EPA concedes that it earlier "rejected similar approaches" to that it now proposes, and expressly rejected a 150 millirem/year standard as one that "no regulatory body we are aware of" considered acceptable. 70 Fed. Reg. at 49031. Absent from EPA's new discussion is any reason to believe regulatory bodies would now consider that standard, much less one more than twice as lenient, acceptable for the general public. Instead, EPA's rationalizations seem to underscore the arbitrary and legally dubious nature of the new proposed rule. Most notably, EPA does not explain how its previous conclusion that such levels were inconsistent with the NAS's recommendations can now be dramatically reversed.

EPA suggests its rule is “unprecedented” because it was commanded by NAS and the Court to address time periods after 10,000 years. But that is no rationale. EPA never explains how a standard that is obviously inadequate can suddenly become adequately protective at 10,001 years. Nor can it, for EPA has no basis for assuming that human susceptibility to radiation will change. Additionally, EPA’s suggestion that it need not be consistent with international precedents, because those precedents do not address long time frames, is demonstrably false. Many international and national bodies do recommend or impose regulation over long time frames, and none permits the type of two-orders-of-magnitude increase in risk that DOE’s non-protective second-tier standard would allow. *See* Appendix A.

VII. The Proposed Rule Poses Unacceptable Public Health Risks

EPA's proposed rule is totally lacking any analysis of the health and safety implications of a 350-millirem (1000-millirem mean equivalent) standard. This is a remarkable oversight, particularly in light of the hundreds of thousands of years following peak dose that the waste will continue to be dangerous. Nevada is aware of no instance in which EPA has promulgated a health and safety standard without analyzing its health and safety effects. Such an oversight is not merely arbitrary and capricious; it represents irresponsible abdication of EPA's Congressionally defined regulatory role.

Had EPA performed any such analysis, the results would be obvious: the proposed standard creates a virtually limitless future of unreasonable risks. Nevada's health and safety consultant has completed the very analysis that EPA has declined to perform, and concludes (based on accepted correlations between radiation dose and adverse health effects) that exposure to a 350 millirem additional annual dose over a lifetime would create a 4.8 percent increase in adult risk of fatal cancer. Furthermore, the radiation dose that could be received in three to six years would be in the range over which a 40 percent increase in the cancer rate in children has been directly observed. *See* Dr. M. C. Thorne, *International Literature and Health Effects of an Annual Effective Dose of 350 mrem* (Nov. 10, 2005), attached at Appendix A. EPA offers no rationale explaining why such increases are acceptable. It should come as no surprise that the President of National Council on Radiation Protection (the premier expert U.S. body on radiation standards and science) strongly criticized the EPA proposal as inconsistent with long established national principles of radiation protection at a November 14, 2005 presentation to NRC’s ACNW.

There are strong reasons to be concerned about the unprecedented magnitude of the health risks posed by the EPA rule. As noted in a recent analysis of EPA's new Yucca rule, the International Atomic Energy Agency's ("IAEA's") 2001 peer review observed that the government's own Yucca studies revealed potential uncertainties in projected radiation doses of four or more orders of magnitude. *Id*. at 35. Projected radiation exposures at Yucca could therefore be 10,000 times too high or 10,000 times too low.

Dr. Thorne has provided a summary of the international literature and regulations concerning dose standards to further support the view that 350 millirem/year constitutes an unreasonable and dangerous incremental anthropogenic radiation source. The full text of Dr. Thorne's report must be taken into account. He concludes among other things that EPA has selectively and misleadingly quoted from overseas and international sources in an effort to support its rule, and that the rule would allow an increase in cancer risk that no other regulatory body considers acceptable, even for geologic disposal. *See* Appendix A.

VIII. The New Standard is Unprecedentedly Lenient and Out of Compliance with Radiation Protection Standards Worldwide

The unacceptable health risks posed by EPA's proposed 350 millirem/year (1000 millirem/year mean equivalent) standard should not be surprising, for a 350 millirem standard is higher than anything EPA, or any other regulatory body, ever has approved before. The NAS report recognized an existing international consensus supporting substantially more stringent protections. *See* NAS Report at 41. NAS recommended a starting point for EPA's rulemaking consistent with that international consensus. As EPA itself has acknowledged, that would produce a standard in the range of 2-20 millirem/year, far lower than the standard EPA now proposes.

In its prior rulemaking, EPA recognized that deviating from this international consensus and from this NAS recommendation would be inappropriate, and rejected as unsafe proposals to set standards well below the 350-millirem standard it now proposes. When commenters on the original 40 C.F.R. Part 197 suggested a standard gradually decreasing in stringency, EPA responded harshly, noting that "*no regulatory body we are aware of considers doses of 150 mrem to be acceptable*." EPA, Response to Comments at 3-8 (2001) (emphasis added). Likewise, EPA rejected a commenter's suggestion of a 25 millirem standard—which is more than *ten times lower* than the standard EPA now proposes—because that standard would be "(1) higher than that recommended by the NAS…; (2) inconsistent with [EPA's] generic disposal standards at 40 CFR. part 191…; and (3) even further outside the preferred EPA lifetime risk range." *Id.* at 4-5. And EPA

> disagree[d] particularly strongly with the commenter who recommended a 70 mrem standard as adequately protective. The risk level associated with 70 mrem is about five times as high the risk level associated with the individual-protection limit. This is well above the NAS-recommended level and unprecedented in the current regulations of this and other nations for this activity. It also is significantly inconsistent with the individual protection limit of 15 mrem CEDE/yr in our generic standards (40 C.F.R. Part 191). This would result in a risk level at Yucca Mountain that is

significantly higher than that at any facility that falls under 40 C.F.R. Part 191.

Id. at 4-5 to 4-6.

Those past conclusions indicate that EPA has consistently viewed proposed standards much lower than the one it now proposes as unprotective of public health, internationally unprecedented, and beyond the limit of responsible regulation. This also applies to the EPA's proposal to adopt a two-tiered approach to the human intrusion performance assessment.

IX. <u>The Collusive History of the Proposed Rule Undermines Its Integrity as a Public Health-Based Standard</u>

Neither EPA's 40 C.F.R. Part 197 rulemaking (published in 2001) nor its current, revised proposal are the product of its independent judgment about the health and safety of the citizens of the United States. Like its predecessor, the proposed rule reflects the wholesale adoption of standards pushed on EPA by DOE and its industry allies as representing merely the standards *that could be met* by a repository at Yucca, not the standards that would protect the public health and safety in fulfillment of EPA's statutory responsibilities. As a result, the current proposal is not the product of reasoned decision-making and does not constitute a public health-based standard, as required by the Energy Policy Act of 1992.

A. <u>EPA's Initial Part 197 Rulemaking</u>

Congress required the EPA Yucca standard to be "based upon and consistent with" the recommendations of the NAS. But the ink had barely dried on NAS's 1995 report when DOE began applying pressure on EPA to adopt a standard that DOE believed it could meet at Yucca, the NAS report notwithstanding. As early as October 17, 1995, in a presentation before the Nuclear Waste Technical Review Board ("NWTRB"), DOE outlined its planned campaign to secure a standard Yucca would pass. DOE told the Board it was critical for EPA to carefully consider the time frame over which quantitative compliance would have to be demonstrated, and the level of risk which would be set, calling these standards outcome-determinative because the standards would determine whether "the site can either pass or fail." 10/17/1995 NTRB Transcript, at 15. DOE said it would be working with EPA during the rulemaking process in order to come up with a standard DOE would consider "implementable." *Id.*

In January 1996, then-OCRWM Director Daniel Dreyfus admonished both EPA and NRC that they needed to be very careful in addressing the NAS recommendations in their rulemaking actions, insisting that "whatever standard results from this process . . . must be implementable." Dreyfus further insisted, "Promulgating a standard that cannot be implemented may result in the *de facto* rejection of the Yucca Mountain site, or even a rejection of the option of geologic disposal. Such rejection will not avoid the consequences of long-term radioactive waste management, it will simply require society to resort to a different, and currently undetermined, long-term approach." 1/30/1996 Statement to NRC by D. Dreyfus, at 16.

Despite NAS's explicit direction to the contrary, DOE urged in a public meeting before the Advisory Committee on Nuclear Waste (ACNW) that "a time frame of no longer than 10,000 years" should be established for regulatory compliance, because "the longer the compliance time frame, the more difficult it would be for DOE to succeed in getting a license." 3/27/1996 ACNW Presentation by S. Brocoum, at 4. DOE threatened that "requiring quantitative compliance for periods over 10,000 years could significantly affect the viability of geologic disposal." *Id.* at 13. New OCRWM Acting Director Lake Barrett followed up with a public prediction that DOE could submit a License Application as early as 2002, but only "if we have reasonable EPA and NRC regulatory criteria." 4/30/1996 NWTRB Transcript, at 16. At the same time, DOE reiterated to EPA its need for both a compliance period limited to 10,000 years and a generous dose limit on the order of 100 millirem/year (4/30/1996 NWTRB Presentation by S. Brocoum, at 12), a figure far higher than any EPA standard then in existence from one radioactive source.

In October 1997, Barrett wrote to the NWTRB, urging that EPA and NRC adopt lenient standards and predicting severe consequences for their failure to do so. He cautioned that "[i]t is incumbent upon all knowledgeable participants in this process to be sure that the regulatory framework for the repository . . . is not constructed so as to defeat the nation's policy of geologic disposal." 10/22/1997 Written Statement by L. Barrett to NWTRB, at 6.

EPA's own documents confirm that it was working, in lockstep with DOE, to provide a standard Yucca could meet. In an economic analysis supporting the 2001 version of Part 197, EPA chronicled DOE's answers to a series of questions, none of which were relevant to determining what standard would protect public health and safety. Evaluation of Potential Economic Impacts of 40 C.F.R. Part 197: Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada" (EPA, June 2001). Could DOE meet a strict standard at Yucca; and if so, for how long? If DOE were only able to meet a strict standard for a limited time, what was that time limit? How high did it expect doses to rise after that limited time? EPA had reason to ask, and answer, those questions only if it was attempting to determine what standards Yucca could pass.

The answers to those questions assured EPA that its 10,000-year limit would give DOE the pass it wanted. EPA well knew, as illustrated by the graph below taken from the EPA's rulemaking record, that extending the time of compliance with its 15 millirem/year standard to the peak dose would doom Yucca. So, ignoring the NAS recommendation and EnPA, it acquiesced to the 10,000 year cut-off desired by DOE. In this same economic analysis, EPA boasted that it had done what DOE had asked and even more: EPA said its Part 197 would not require DOE to abandon Yucca Mountain or even spend one additional dollar in order to comply with the radiation standard. *Id.* at ES-2.

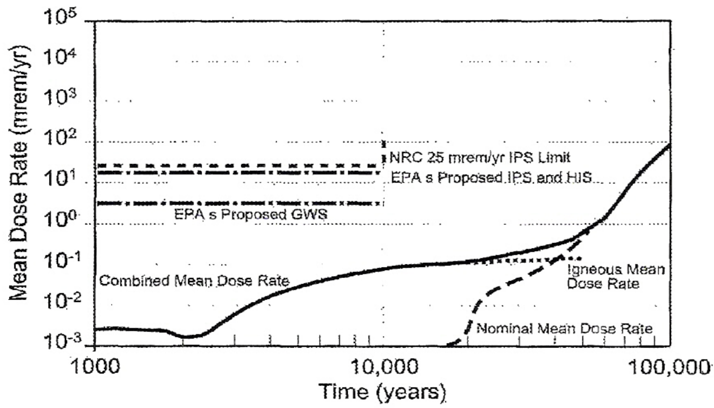


Figure 3-2 Comparison of Proposed Radiation Protection Standards with Expected Values of TSPA-SR Calculations for a Repository at Yucca Mountain for Nominal and Igneous Scenarios (Figure adapted from TRW00a).

EPA knew from DOE data of the ineffectiveness of the natural setting at Yucca to isolate waste, DOE's near total reliance on engineered waste containers, and DOE's calculations demonstrating that the waste containers might isolate wastes for 10,000 years but would certainly fail thereafter. Accordingly, EPA's 2001 Part 197 accommodated DOE completely, setting both a time of compliance and a dose level that DOE had advised EPA it could meet, and at the same time avoiding either a time of compliance or a dose level that DOE had advised it could not meet. The process had nothing to do with applying a health-based standard.

B. EPA's Current Proposed Rulemaking

The July 2004 *NEI* decision unsurprisingly focused on the NAS finding and recommendation that there was no basis for selecting a 10,000-year time of compliance and that the standard promulgated by EPA should provide protection to the time of peak risk or dose (which could be much later). The court's decision did not find a 15 millirem/year standard inappropriate for public health and safety, but it found EPA had no justification for eliminating that protection for future generations who might be born after 10,000 years. So EPA was sent back to the drawing board to develop a standard for peak dose whenever it might occur (within the time period of geologic stability).

DOE quickly stepped in to forestall the obvious solution to EPA's legal problem (*i.e.*, simply extending the 15 millirem/year standard out to the time of peak dose). On August 2, 2004 and November 24, 2004, EPA sat down with DOE representatives from the Yucca project to discuss how best to revise 40 C.F.R. 197 in order to satisfy the Court's mandate that it cover a time period beyond 10,000 years, while at the same time somehow ensuring its "implementability" by DOE. *See* 1/27/2005 EPA FOIA Response, at 3-7. The exact words spoken at those meetings may never be known, because EPA is concealing under a claim of privilege everything discussed and agreed to by EPA and DOE. *Id.* at 1. In asserting the privilege, EPA confessed that the withheld documents "reflect the internal discussions, advice, analysis, and recommendations that were being considered during meetings between EPA and DOE officials regarding aspects of very long-term modeling and their effect on EPA's response to the NEI decision." OAR-2005-0083-0028, at 3. EPA also described the withheld meeting notes as "discussions among senior EPA program and legal staff of EPA, NRC, DOE, and the Department of Justice concerning various legal options to respond to adverse rulings in the *NEI* decision." *Id.* Appendix at 2, 4.

Before initiating the current proposed rulemaking, EPA took another step to ensure any revised standard it might adopt would accommodate DOE. It hired S. Cohen & Associates to do a detailed analysis of DOE's Yucca Mountain performance assessments. The Cohen report confirmed that, despite DOE's tinkering with various inputs to its performance model since EPA's 2001 rule had been promulgated, certain basic premises persisted:

- DOE at Yucca could meet a strict 15 millirem/year dose standard for the short term, perhaps for as long as 10,000 years if the waste packages lasted that long.

- Over a longer period, after the inevitable failure of engineered barriers, the dose standard would have to be *much* higher if there was to be assurance Yucca could go forward.

Cohen's Figure 12-3 (DOE's Figure 1-13) below provides an illustration, showing the projected doses from Yucca over a time frame of one million years.

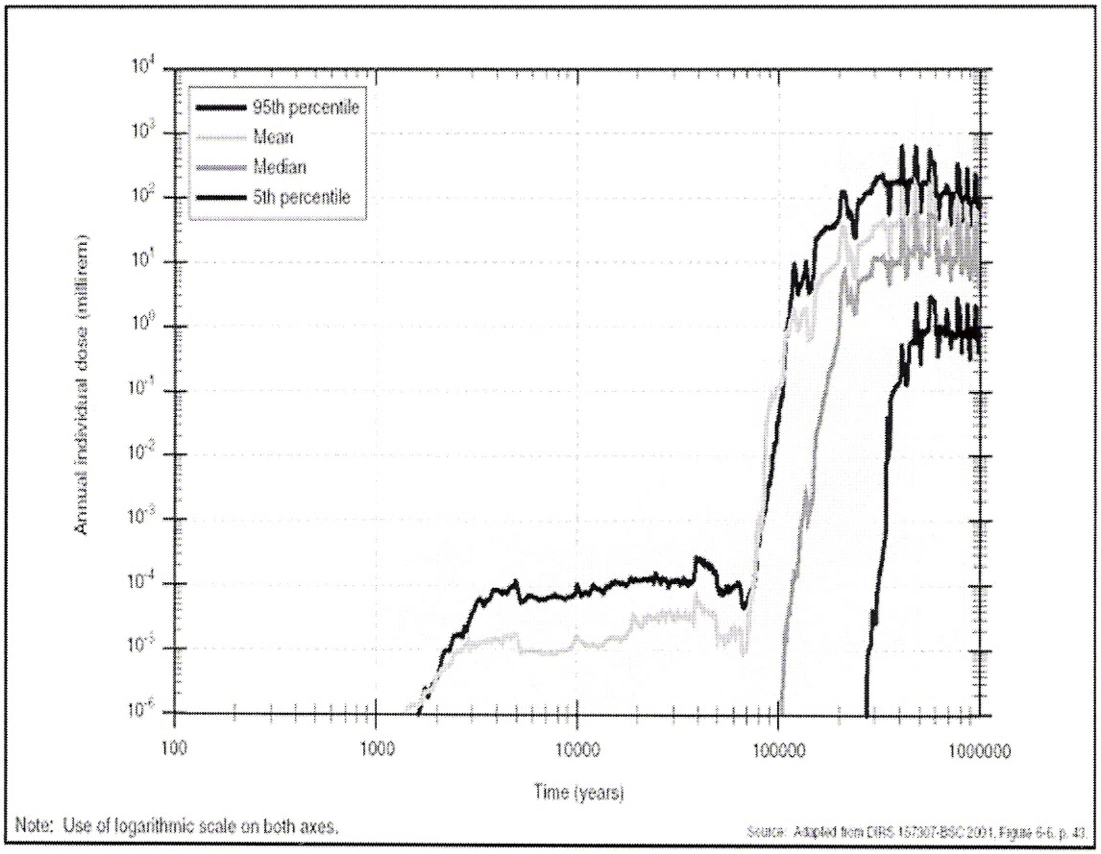


Figure I-13. Total annual individual dose at the RMEI location for 300 probabilistic simulations of the lower-temperature operating mode for the Proposed Action inventory, nominal scenario; the figure also displays the 5th-percentile, median, mean, and 95th-percentile values of these simulations.

Figure 12-3. Revised Supplemental TSPA One-Million-Year Dose Histories Based on the FEIS Lower-Temperature Operating Mode

Cohen essentially encouraged DOE not to make any further effort (relating to either natural or engineered barriers) to reduce the uncertainty level in its projections, telling EPA to expect no such action by DOE because it would adversely impact the repository's cost and schedule:

> The larger uncertainties in projected dose rates for long compliance time frames, in comparison with uncertainties for time frames on the order of 10,000 years, lead to consideration of two basic types of actions aimed at increasing confidence in dose rates submitted for licensing reviews. One is to increase the site characterization database, with the objective of increasing confidence in assessed performance of the *natural system*. The other is to augment the barrier features of the *engineered system*, with the

objective of increasing the resistance of the system to degradation as a result of water contacting the waste form. Both types of action would extend the time to readiness for licensing reviews, and both would incur major costs.

OAR-2005-0083-0085, at A-20, 21.

Cohen observed, "Because DOE is not expected to make changes, undertake significant site characterization, or drastically revise its performance approach or models as a result of EPA's revisions to the 2001 rulemaking, there are no costs directly attributable to EPA's rulemaking." *Id.* at 2-4. Thus, for the second time, EPA knowingly refrained from proposing a Yucca standard that might require DOE to spend an extra dollar.

C. <u>OMB's Role in EPA's New Proposal</u>

Presumably at the direction of DOE, the Office of Management and Budget ("OMB") instructed EPA to remove a provision from the draft proposed rule, circulated for comment to OMB, providing that "NRC may specify, in regulation, additional features, events, and processes ["FEPs," *see* Section XIX below] that DOE must consider because they may significantly affect the magnitude of the peak dose." EPA obliged, and that provision, which would have confirmed NRC's authority to apply traditional principles of performance assessment in its licensing review, was removed. As a result the rule is not risk informed. It arbitrarily eliminates factors that could significantly affect the calculation of the peak dose.

D. <u>The Nuclear Industry's Role in EPA's New Proposal</u>

The nuclear industry's research organization, the Electric Power Research Institute ("EPRI"), also weighed in with its proposals for ensuring that EPA promulgated a new standard that DOE could meet at the inferior geologic location of Yucca Mountain. Interestingly, the organization which prepared EPRI's "Yucca Mountain's Licensing Standard Options for Very Long Time Frames" (Apr. 2005) for submission to EPA was Monitor Scientific, LLC, whose website presently features EPRI, yet also brags that "Monitor's expertise has been used to support EPA in projects related to . . . the 2001 Yucca Mountain rulemaking." *See* http://www.monitorsci.com/projects.htm. The Monitor Scientific report delivered to EPA by EPRI also begged for an "implementable" standard. Among other things,

- EPRI recommended that future climate states be established by rulemaking; specifically, EPRI recommended that future climate be fixed to the present interglacial classification, despite the fact that it conceded, "It is improbable that, except for brief intervals, the earth's climate during the next 1,000, 10,000, 100,000, or 1,000,000 years will replicate that during human-recorded history." OAR-2005-0083-0079, at A-19.

- EPRI urged that EPA retain the 15 millirem/year standard for 10,000 years, but specify a different, higher dose limit to future generations after 10,000 years, as a separate stand-alone provision that would not alter the existing requirement for the first 10,000 years. This two-tiered standard for dose/time of compliance was critical "if the regulation . . . is to remain implementable," EPRI said. *Id.*

- EPRI recommended a different approach to establishing which FEPs were required to be included in DOE's compliance assessment and argued for no additional FEP screening for the time period beyond 10,000 years, a point evidently later also impressed upon OMB. *Id.*

EPRI delivered its report to EPA on April 11, 2005, urging that its proposals "would be 'reasonable' and implementable in a regulatory environment." 4/11/2005 Kessler Email, at 2. With DOE and nuclear industry parameters in hand, EPA proposed a rule which honored DOE's and the nuclear industry's essential requests by setting a dose standard beyond 10,000 years that should be high enough to be ensure implementability of the Yucca project, notwithstanding science and law to the contrary. Significantly, in selecting a 350 millirem/year long-term standard, and using the median as the measure of compliance, EPA went even further to accommodate DOE than the 100 millirem/year (mean equivalent) second-tier standard that even EPRI had found pushed the bounds of reasonableness.

X. <u>EPA's Proposed Standard Irrationally Abandons the Apportionment Principle</u>

EPA's proposed rule would abandon the well-established and universally accepted principle of apportionment. That abandonment departs, without any credible justification, from the consensus position embodied in the NAS's recommendations and in EPA's own prior statements and practice.

As the NAS report explained:

> [A] general consensus exists among national and international bodies on a framework for protecting the public health that provides a limit of 1 milliSievert (mSv) (100 millirem (mrem)) per year effective dose for continuous or frequent exposures from all anthropogenic sources of ionizing radiation other than medical exposures. A general consensus also appears to exist among national authorities in various countries to accept and use the principle of apportioning this total radiation dose limit among the respective anthropogenic sources of exposure, typically allocating to high-level waste disposal a range of 0.1 to 0.3 mSv (10 to 30 mrem) per year.

NAS Report at 4; *see also id.* at 40-41. Using this approach, each individual source is allocated not the entire amount of radiation that would reach the regulatory limit, but only a portion, based on the reasonable assumption that other sources will exist, and that people's health will depend upon the cumulative risks that all of those sources create.

Until releasing its proposed rule, EPA has consistently adhered to this internationally accepted apportionment principle. For example, in 1993, in its WIPP standards, EPA explained that its chosen 15 millirem/year standard

> is consistent with the ICRP approach of apportioning an overall dose limit from man-made radiation to particular activities, such as waste disposal. The ICRP suggests using an overall limit of one milliSievert CED (100 millirems CED) per year. While EPA has not established such an overall limit, the Agency finds that 15 millirem CED per year is today an appropriate and acceptable fraction of the 100-mrem ICRP recommendation because it is small enough to ensure that the total exposure of an individual who was exposed to a number of sources would stay below the overall limit.

58 Fed. Reg. 66398, 66402 (EPA, Dec. 20, 1993).

Likewise, in 1994, in proposed rules applicable to nuclear radiation exposures, EPA explained that

> there are many different categories of activities using radiation that can lead to exposure of members of the public. These currently include medical uses of radiation and their supporting activities; nuclear electric power facilities and their supporting fuel cycle facilities; research and industrial users; weapons production, storage, and disposal facilities; technologically-enhanced exposure to natural radiation sources; consumer products; space applications; disposal sites for radioactive wastes; and decommissioned sites at which radioactive materials were formerly used. It is therefore also necessary to ensure that total doses to individuals, who may be exposed not only to more than one source in a given category in a few cases, but more often to a number of different categories of sources at one time, are not likely to exceed the [total allowable dose].

59 Fed. Reg. 66414, 66423 (EPA, Dec. 23, 1994). Based on public health studies, EPA determined that "combined radiation doses incurred in any single year from all sources of exposure covered by these recommendations should not normally exceed a Radiation Protection Guide of 1 mSv (100 mrem) effective dose equivalent to an individual." *Id.* at 66420.

EPA adhered to, and relied upon, this guidance in the initial stages of developing the Yucca standard. In a report entitled "Environmental Radiation Protection Standards for Yucca Mountain: Considerations on Issues," EPA's Team Leader for developing the Yucca standards explained that

> the agency has proposed [a 100 millirem/year dose] as an acceptable level for members of the public exposed from all sources except background and medical exposures [citing EPA's December 1994 proposed standards]. The EPA, and international guidance, then requires that this overall dose be apportioned among actual and currently known potential sources and future exposures. In the vicinity of Yucca Mountain are several potential sources of exposure for a critical group, for example, the waste disposal site in Area 5 and the weapons testing areas on the Nevada Test Site, the commercial low-level radioactive waste disposal site near Beatty, Nevada, and a potential interim storage site for spent nuclear fuel.

See Raymond Clark, Environmental Radiation Protection Standards for Yucca Mountain: Considerations on Issues (1988), at 5 (a copy of which is submitted by Nevada with its comments).

EPA's final rule again adhered to this principle, setting the site-specific dose limit at 15% of the total allowable 100 millirem/year dose. EPA explained that

> [t]he apportionment of the total dose limit among different sources of radiation is used to ensure that the total of all included exposures is less than 1 mSv (100 mrem) CED/yr. Thus, ICRP recommends that national authorities apportion or allocate a fraction of the 1 mSv (100 mrem)-CED/yr limit to establish an exposure limit for SNF and HLW disposal facilities. Most other countries have endorsed the apportionment principle.

66 Fed. Reg. at 32089. EPA went on to explain that its 15 millirem/year standard "is 15% of the ICRP-recommended total dose limit. It falls within the range of standards used in other counties and the range recommended by NAS, and is also consistent with the individual protection standards in 40 CFR part 191." *Id*.

In its responses to comments on Part 197, EPA relied directly on this apportionment principle in rejecting a suggested 70 millirem/year standard. EPA explained that "70 mrem from one source is too high a proportion of the annual 100 mrem recommended by the NCRP and ICRP (excluding background, occupational, accidental and medical sources). The apportionment of the total dose limit among different sources of radiation is used to insure that the sum, or total, of all included exposures is less than 1 mSv (100 mrem)." EPA, Response to Comments, 4-5 to 4-6 (2001). EPA then reiterated that ICRP recommends national authorities allocate "a fraction" of the 100 millirem total to establish an exposure limit for spent fuel and high-level waste disposal facilities. *Ibid.*

Yucca Mountain presents (and EPA has provided) no reason to abandon this concept. The proposed repository cannot be the sole source of local radiation, for, as EPA itself has noted, the area surrounding Yucca Mountain already has borne more than its fair share of the nuclear era's impacts.

> There are multiple sources of potential radionuclide contamination on or near [the Nevada Test Site], one of which is the Yucca Mountain site. Portions of NTS have been subjected to both underground and aboveground weapons detonations. A substantial quantity of radionuclides was created by these tests. An estimated inventory of 300 million curies remains underground…. Elsewhere in the NTS, DOE is burying [low-level waste] in near surface trenches and TRU radioactive waste has been disposed of in the Greater Confinement Disposal facility. Finally, there is a commercial LLW disposal system located west of Yucca Mountain near Beatty, Nevada. Each of these facilities could have releases of radioactivity to the groundwater.

66 Fed. Reg. 32074, 32088 (citations omitted).

All these Nevada-specific exposures would occur *in addition* to the many other anthropogenic exposure sources. As EPA has noted, commercial nuclear power plants, university research and development, experimental reactors, government-controlled reactors, and foreign facilities, among other sources, all contribute radiation. *See* 66 Fed. Reg. at 32079; *see also* ICRP Publication 46, *Radiation Protection Principles for the Disposal of Solid Radioactive Waste* 2-3 (1985) (describing the generation of radiation throughout the fuel cycle). EPA has offered no basis to assume these other sources will cease to affect the Yucca Mountain area.

Nevertheless, EPA's proposed 350-millirem (1000-millirem mean equivalent) second-tier standard would completely abandon the principle of apportionment. EPA would allocate Yucca approximately 3.5 times—or over ten times, in mean-equivalent terms—that total dose standard to *one site*. EPA provides no coherent explanation for this shift. Instead, the proposed rule acknowledges that "in practice today, doses from any particular source of radiation are generally kept to a fraction of the 100 mrem overall limit, in recognition that a person may be exposed to more than one practice or source." 70 Fed. Reg. at 49040. But EPA then makes the remarkable claim that because the agency does not know what future sources will exist, it is appropriate to allocate all of the accepted 100 millirem/year total dose to one source. *Id.* at 49041.

In multiple ways, this statement turns the principle of apportionment on its head. First, the principle always has been applied, in the past, to sites at which other future exposure sources were unknown and unknowable. It would require "immense speculation," for example, to guess what specific sources will be near the WIPP site, but EPA relied on the apportionment principle to establish the WIPP standard. *See* 58 Fed. Reg. at 66402. It would similarly require "immense speculation" to guess what specific sources will exist at Yucca Mountain over the next 10,000 years, yet in promulgating its original 10,000-year standard, EPA again applied the apportionment principle. 66 Fed. Reg. at 32089. The prerequisite for application of this principle has never been foreknowledge of particular future sources at the site in question; nuclear waste disposal systems are inherently long-lasting, and we never know exactly what other sources will exist.

Indeed, that very lack of knowledge is a core reason for utilizing apportionment, not a reason to abandon the principle. Since EPA does not know what will happen in the future, but does know that other sources are possible—indeed, they are inevitable if we continue our current practices of using nuclear materials—it must make accommodations for those potential sources. As the ICRP explained, in the publication that for two decades has formed the foundation of EPA's apportionment policy,

> [t]o allow for dose contributions from present practices *and to provide a margin for unforeseen future activities*, the Commission recommends that national authorities select a fraction of the dose limits as a source upper bound for each source of exposure, to ensure that the exposure of individuals will remain below the relevant dose limit.

ICRP Publication No. 46 at 11 (emphasis added). EPA's approach, by contrast, is the equivalent of assuming that other sources will never affect the vicinity of Yucca Mountain—despite EPA's own statement that it would involve "immense speculation" to predict such future events. *See* 70 Fed. Reg. at 49041. In the guise of avoiding speculation, EPA proposes to make an unprecedented, absurdly optimistic, and totally speculative assumption.

This rationale also ignores additional sources that *already exist*. EPA itself has repeatedly pointed out that "[t]here are multiple sources of potential radionuclide contamination on or near [the Nevada Test Site], one of which is the Yucca Mountain site." *See* 66 Fed. Reg. at 32088 (also quoted above). Specifically, NTS contains residual radiation from 1054 above-ground and underground nuclear weapons tests, the still-contaminated 1960s rocket test area (Area 25) adjacent to Yucca, the no-longer operating Greater Confinement Disposal Area, in which about 9.3 million Curies of the equivalent of Greater Than Class C waste are buried in vertical shafts, and areas of ongoing disposal of low-level waste, with about 500,000 Curies already buried. BID, Appendix II, Table II-1. The Beatty commercial low-level waste disposal facility is located in Amargosa Valley, also up-gradient from the valley population; when it was closed in 1992 the Beatty low-level waste shallow landfill contained 641,000 Curies of waste. EPA's blithe suggestion that Yucca Mountain will be the only source worth considering thus ignores present reality as well as the unpredictability of the future.

Further sources also are a foreseeable possibility. Given its past and current uses, other sources of radioactive contamination may be installed at the Nevada Test Site. For example, there is current discussion of reorganizing the entire U.S. nuclear weapons complex onto a single site in the future, and the Nevada Test Site has been considered by the government for such future use. All of the current weapons complex sites are in some stage of clean-up, suggesting that any new location of the complex would be subject to some level of contamination.

EPA supplies no other attempted justification for diverging from the NAS's recommended approach, its own past practice, and worldwide convention. Its abandonment of apportionment therefore is arbitrary, capricious, and inconsistent with the EnPA's mandate that EPA's rule be "based upon and consistent with" the NAS report's recommendations.

XI. <u>The Proposed Rule Unlawfully Permits Calculations Based on the Median, Not the Mean, of Exposure Predictions</u>

Appendices B and C to these comments contains a more detailed statistical and mathematical evaluation of this issue by Dr. B. Thomas Florence, Dr. Thomas Vasquez, and Dr. Thorne. *See* B. Thomas Florence and Thomas Vasquez, ARPC, *Some Comments on the Proposed Yucca Mountain Compliance Standards* (Oct. 15, 2005) ; Dr. M. C. Thorne, *The Role of Uncertainties in Defining the Proposed Standard* (Nov. 10, 2005), attached as Appendices B and C. The full text of Appendices B and C must be considered.

Departing from the recommendation of the NAS, its own past and present practice, and the past practice of the NRC, EPA's proposed rule would use the median,[1] rather than the arithmetic mean, of projected doses from its Yucca performance simulations to measure compliance during the post-10,000-year period. That is a highly significant shift; DOE's current modeling predicts that at peak dose, mean values will be approximately *three times higher* than median values, and a 350-millirem median standard is thus the equivalent of an approximately 1000-millirem mean standard. Because EPA proposes to continue using the mean, which it accurately describes as a "familiar and well-understood statistical concept," for its 15 millirem pre-10,000 year period, *see* 70 Fed. Reg. at 49042, its post 10,000-year standard will be almost *seventy* times higher than its pre-10,000 year standard. This shift may be (and appears calculated

[1] The arithmetic mean of a set of numbers is the average number. That is, it is the outcome produced by adding up each individual number and dividing by the total of the numbers. The median, by contrast, is merely the midpoint of all numbers. For some data sets, the mean and median may be close, or even equal. For example, if the numbers in set A are 1, 2, 3, 4, and 5, both the mean and median will be 3. Other sets, however, have radically divergent means and medians. If, for example, the numbers in set B are 1, 2, 3, 10, and 24, the median is 3, but the mean is 8—more than twice as high. Though sets A and B obviously are quite different, that difference is captured only by the mean; the median for both sets is exactly the same. The real-world implications of this distinction can be crucial. Imagine, for example, that the safety of a city's proposed levee system is assessed by modeling five anticipated storm scenarios, and model runs for the five different scenarios predict 0, 1, 4, 45, and 650 deaths. The median prediction would be four deaths—a number that engineers might decide was acceptable, or required only minimal changes to the proposed levee system. The mean, prediction, however, would be 140 deaths—a very different number. If the engineers consider only the median, they may allow an unreasonable level of risk.

to be) outcome-determinative; DOE's TSPA modeling suggests that Yucca could just barely meet a median-based standard, but would grossly fail a standard based on the mean.

For several reasons, this shift to the median is flawed. First, the NAS expressly recommended the use of the mean. Second, using the median is inconsistent with EPA's own past and present statements and practice, and EPA has offered no rational explanation for the shift. Third, EPA's approach is scientifically and statistically unsound. Finally, use of the median would allow a grossly unsafe site to be licensed; though DOE's current modeling projects that the median dose will be below 350 millirem/year, 42 percent of the modeling runs appear to exceed that number. *See* Appendix A, at 8. No site that has a 42 percent chance of failure can ever be considered adequate.

A. <u>EPA's Abandonment of the Mean Departs from the NAS's Recommendation</u>

In its Technical Bases Report, the NAS could not have been more clear: "We recommend that the *mean* values of calculations be the basis for comparison with our recommended standards." NAS Report at 123 (emphasis added). Since EPA's rule must be based upon and consistent with the NAS's findings and recommendations, that recommendation mandates the use of the mean.

Yet EPA has not only failed to implement that recommendation; it has pretended it doesn't exist. EPA falsely claims that "NAS in its recommendations did not speak explicitly to any particular performance measure to be used in determining compliance with regulatory standards." 70 Fed. Reg. at 49043. That obviously is not true.

B. <u>EPA Departs from its Own Past and Present Use of the Mean</u>

EPA's shift from the mean to the median also marks a dramatic departure from EPA's prior approach. In its prior rulemaking, EPA initially proposed to use the *higher* of the mean or median, and eventually settled on the mean as its chosen compliance measure.

In the 1999 proposed rule for Part 197, EPA stated that: "As a result of the performance assessment there will be a distribution of the highest potential doses incurred by the RMEI [Reasonably Maximally Exposed Individual]. We are proposing that the mean or median value (whichever is higher) of that distribution be used by NRC to determine compliance with the individual protection standard." 64 Fed. Reg. 46988.

> In the June 2001 Final Rule, EPA stated: "*We propose a compliance measure we believe is reasonable but still conservative: the mean of the distribution of projected doses from DOE's performance assessment*. The primary reason we propose this requirement is that it provides a necessary context for implementation of the standard.... We believe that a thorough

> assessment of repository performance expectations should examine the full range of reasonably foreseeable site conditions and relevant processes expected during the regulatory time frame…."

66 Fed. Reg. 32125 (emphasis added). EPA went on to consider many of the rationales it now offers for selecting the median, but it rejected them, concluding instead "that, in the case of Yucca Mountain, the mean is an appropriate measure." *Id.*

In its June 2001 Responses to Comments in its prior rulemaking on Part 197, EPA similarly made clear that it would employ the mean rather than the median (emphasis added in each):

> Page 4-11: "Note that while we proposed using the higher of the mean or median, *in our final rule we specify that the mean be used* (see Section 7 of this document for a full discussion of our decision on this point.)"
>
> Page 7-3: "In line with EPA's use of the term 'reasonable expectation,' *the fundamental compliance measure consistent with the literal interpretation of this term would be the mean value* of the distribution of calculated doses."
>
> Page 7-3: "Although we proposed using the higher of the mean or median, *after further consideration we believe that the mean alone will be an appropriate measure of compliance*. We believe this approach is sufficiently conservative in that it leans toward giving greater weight to calculations that result in higher exposures, without being overly influenced by 'worst-case' and possibly extreme low-probability situations."
>
> Page 7-4: "*We have specified only that the mean of the dose assessments must meet the exposure limit*, without specifying any statistical measures for the level of confidence necessary for compliance, such as 95 or 99% confidence level for the mean. We believe setting a confidence level is clearly an implementation function that should be left to NRC…."
>
> Page 7-5: "*...EPA believes that the mean will reflect the effects of high dose situations sufficiently* and we do not feel the alternatives proposed are compatible with our approach."
>
> Page 7-6: "Because it is possible to observe skewed parameter distributions, a non-uniform dose distribution is not unexpected. Nevertheless, *we believe that use of the mean alone will adequately address these questions*."

In proposing to use the median rather than the mean, EPA also would deviate from the practice of the NRC, which in its prior Yucca Mountain rule also specified that the mean would be used. In responses to comments, the NRC explained why the mean was the appropriate measure. Initially, it explained that the mean was consistent with the recommendations of the NAS:

> NAS recommended a performance objective for Yucca Mountain based on risk to an individual. Proposed part 63 defined "risk" to an individual as being proportional to two factors: (1) The dose to the individual from exposure to ionizing radiation and (2) the probability of the individual receiving that dose. Analyses conducted by NRC staff demonstrate that the mean annual dose correctly expresses the risk from radioactive exposure to the individual.

66 Fed. Reg. at 55752 (November 2, 2001). Additionally, NRC explained the statistical justification for selecting the mean rather than the median:

> The Commission expects that performance assessments conducted by [DOE] in support of any potential license application will use probabilistic methods to simulate a wide range of possible future behaviors of the repository system. Each possible future behavior of the repository system is represented by a curve describing the annual dose to the RMEI as a function of time. Generally, but not necessarily, each of the possible curves is assumed to be equally likely. Because none of these possible futures can be demonstrated to describe the actual future behavior of the repository system, the Commission requires that the applicant calculate the mean of these dose versus time curves, properly weighted by their individual probabilities.

Id. In other words, because no model run outcome is assumed to be more likely than any other modeling run, the mean, which treats each run as equally important, is more appropriate than the median, which treats higher, more dangerous outcomes as less important outliers. In contrast, the median artificially discounts high dose realizations (the distributions tend to be positively skewed) simply because they are high, with no justification in sound science, and notwithstanding that the doses are already weighted by their associated probabilities. Put another way, use of the mean violates the principle that all realizations are presumed to be of equal weight, absent some actual investigation of particular outliers that would raise questions about their scientific validity.

C. <u>EPA Lacks Any Rational Basis for Abandoning the Mean</u>

EPA's proposed rule offers no reasonable basis for diverging from the NAS's recommendation and from its own past practice, or for using one compliance measure for the pre-10,000-year period and another for the post-10,000-year period. Primarily, EPA cites uncertainties about Yucca Mountain and perceived "over-conservatisms" in DOE's modeling. These uncertainties and supposed over-conservatisms, EPA claims, call into question the higher values in DOE's modeling, and suggest that a performance measure that devalues those higher values is appropriate. EPA suggests that these uncertainty and over-conservatism problems are greater in the post-10,000 year period, and therefore suggests that its switch from mean to median at 10,000 years is somehow justifiable.

These explanations lack any logic or rationality. First, none of these explanations can mask the blatant inconsistency with the NAS's recommendations. The NAS stated that EPA should measure compliance at the time of peak dose, that there was no scientific basis for distinguishing between the pre-and post-10,000-year periods, and that EPA should use the mean as its measure of compliance. Both in substance and supporting rationales, EPA's proposed rule ignores those recommendations, and thus repeats the EnPA violations that led to the Court's invalidation of its previous Yucca rule.

Second, as discussed in detail in Section XIII of these comments, uncertainty provides no reason for creating a more lax standard, whether that laxity is achieved through a higher numeric standard or a more permissive statistical measure. EPA's mantra-like references to "uncertainty" are inconsistent with its rationale for selecting the median. Also, the premise of EPA's selection of the median is that the median tends to disregard higher repository performance model-run outputs, which EPA says should be treated as less important simply because they are higher. This has no statistical or scientific basis.

Similarly, as discussed in section XIV of these comments, conservatism provides no reason for selecting the median rather than the mean, because conservatism, if it actually existed (the reverse is the case), would be a reason for DOE to fix its modeling, not for EPA to adjust its standard. In any event, as discussed *infra,* DOE's modeling to date suffers not from over-conservatism, but from a gross *lack* of conservatism.

EPA's selection of the median is based on a basic misunderstanding of statistics. EPA's entire premise for selecting the median is that some model runs—specifically, those with higher predicted outcomes—should be given less weight than others. EPA repeatedly states that the median avoids placing "undue" emphasis on extreme events. Yet, as the NRC pointed out in defending the *mean* as an appropriate measure, "[g]enerally, but not necessarily, each of the possible curves is assumed to be equally likely." 66 Fed. Reg. at 55752; *see* Appendix B. In other words, each model run's outcome is as likely as any of the others, and a statistical measure specifically designed to throw out the higher numbers introduces a pronounced, non-conservative, and irrational skewing effect. But the mean is not skewed, as EPA implies, by those higher outcomes; in the averaging process, the results are treated as equally likely and important. No other approach is rational.

The selection of the median is statistically inappropriate for another reason. By selecting the median, which considers only the number, but not the magnitude, of "bad" (i.e. above-the-median) outcomes, EPA has declined to consider the degree of harm threatened by each of those bad events. Use of the median will discourage any investigation of high dose calculations since those high doses will have little or no effect on compliance. Indeed, use of the median will permit a finding of compliance notwithstanding hundreds of dose calculations showing lethal doses of radiation, because the median is insensitive to the actual magnitude of the approximately 42% of the dose calculations above it. As a hypothetical example, if 149 realizations (calculations) showed Yucca Mountain would destroy all of the nearby Nevada residents, but 151 of the realizations showed a dose of less than 350 mrem, the EPA approach would pass the repository. The reality is that for any safety evaluation, the magnitude of any potential bad outcomes does matter, and the mean takes that magnitude into account whereas the median does not. In fact, as Dr. Thorne points out (see Appendix C), the median has no well defined relationship to health detriment, so that EPA's proposed use of the median effectively severs the dose standard from the actual harm it is supposed to prevent. Such a standard is not even health-based, as required by law.

EPA fails to explain why focusing on "bad" outcomes is inappropriate for a safety analysis. Indeed, the typical goal of nuclear safety analysis is to focus precisely on the potential bad outcomes. The core purpose of a health and safety analysis is to figure out what will happen if things go wrong. No one would ever criticize levee builders for focusing on performance during extreme weather events rather than on routine sunny days.

Finally, by discounting the effects of high dose calculations, use of the median also reduces the very uncertainty EPA relies on for its choice of 350 millirem.

For those additional reasons, EPA and NRC acted appropriately in previously selecting the mean as their performance measure, and EPA's proposed abandonment of the mean is irrational, unscientific, and blatantly inconsistent with the recommendation of the NAS.

XII. EPA Arbitrarily Terminates Its Groundwater Protection Standard

In a cursory section of the proposed rule, EPA explains, without any legal or scientific justification, that the proposed rule would abruptly remove any groundwater protection standard at all once 10,000 years have elapsed. That premature abandonment of groundwater protection, at a stage when peak doses may not have already arrived, is ironic and disturbing in light of EPA's vigorous support of its separate groundwater standard in its previous rulemaking and in *NEI v. EPA*, 373 F.3d at 1278-1285, where it successfully defended that standard against aggressive challenges brought by NEI. Moreover, EPA has announced in advance that it will *not even consider comments* regarding "any aspect of the groundwater protection standards." 70 Fed. Reg. at 49024. That rigid determination to terminate the groundwater protection standard without any public comment, which stems from a fundamental misunderstanding of the Court's ruling in *NEI*, is arbitrary and contrary to law.

EPA's principal explanation for its termination of the separate groundwater standard is that it does "not believe the Court's ruling regarding the 10,000-year compliance period applies to the ground-water protection standards which have the same compliance period." 70 Fed. Reg. at 49024. The proposed rule states, "we are not proposing to modify the ground-water protection standards either by extending the period of compliance or in any other respect." *Id.*

Contrary to that premise, the Court's ruling does govern the separate groundwater standard. The court "vacate[d] Part 197 to the extent that it requires DOE to show compliance for only 10,000 years following disposal." 373 F.3d at 1273. In its conclusion, the Court reiterated the same statement, saying "in sum, we vacate 40 C.F.R. Part 197 to the extent that it incorporates a 10,000 year compliance period because, contrary to EnPA section 801(a), that compliance period is not 'based on and consistent with' the recommendations of the National Academy of Sciences." *Id.* at 1315. The groundwater protection standard is a component of Part 197, and it "incorporates a 10,000 year compliance period" and "requires DOE to show compliance for only 10,000 years." The court therefore expressly vacated this portion of the rule, and EPA's conclusion that the decision did not apply to the groundwater standard rests upon clear error.

The reasoning underlying *NEI v. EPA* compels the same conclusion. As the Court held, EnPA requires EPA to avoid inconsistency with the NAS's recommendations in setting all standards. That requirement must extend to the groundwater standard, for the same sentence of section 801(a) that empowers EPA to set standards also requires consistency with the NAS's report. *See* NEI, 373 F.3d at 1315. EPA cannot invoke the half of that sentence that empowers it to set standards yet ignore the other half, which requires that those standards be based upon and consistent with the findings and recommendations of the NAS, and thus any standards it promulgated could not employ a 10,000-year compliance cutoff after the NAS expressly rejected that cutoff. The logic of the court's opinion therefore supports its literal meaning and indicates, contrary to EPA's current position, that the 10,000-year cutoff of the groundwater protection standard has been vacated. EPA therefore cannot re-adopt that cutoff, especially without allowing comment.

EPA is well aware of the history of agency experiences with groundwater protection standards preceding its present proposal, including the appellate ruling in *NRDC v. EPA*, 824 F.2d 1258, 1293 (1st Cir. 1987), in which the court set aside the original groundwater protection requirements in the generic Part 191 radiation rule because the agency failed to allow for "proper notice and comment as required by the Administrative Procedures Act, 5 U.S.C. § 553(c)." History would repeat itself if EPA were to take the outrageous step of finalizing its approach to groundwater in the proposed Yucca rule without allowing other agencies and members of the public a full and fair opportunity to comment on the agency's dubious approach. Yet, EPA has arbitrarily decided not to consider and respond to comments on this critical subject. That decision would effectively preclude the public participation in rulemaking that is "necessary to ensure informed agency decision-making." *NRDC*, 824 F.2d at 1286.

Moreover, the logic of the Court's opinion, and the NAS recommendation upon which it is based, clearly indicate that EPA could not readopt the 10,000-year cutoff even if it did accept comment. The NAS rejected a 10,000-year cutoff because (1) it saw no scientific basis for drawing lines at 10,000 years; and (2) it realized that a 10,000-year cutoff would terminate the standards before the time of peak risk. That reasoning is just as applicable to groundwater protection as it is to individual exposure. The NAS already has concluded that the physical systems at the site, including all those that influence groundwater flow, are sufficiently predictable that there is no reason for cutting off compliance assessments at 10,000 years. And it has similarly noted that there is no sense in cutting off compliance assessments while the risk is just beginning to increase. Indeed, given DOE's assumption that no releases to groundwater will occur prior to 10,000 years, and EPA's ratification (through its agreement with DOE's assumptions about container corrosion) of that assumption, a 10,000-year-only groundwater standard would be nothing more than a public relations maneuver. For that reason, the NAS's recommendations and the Court's holding compel extension of the groundwater standard through peak dose. Indeed, the opinion is devoid of any suggestion that EPA, once it has decided it is necessary to provide a separate groundwater standard, could then adopt a period of compliance that the Court and NAS had expressly rejected.

EPA also fails to articulate any credible ground for terminating the groundwater standard that can be reconciled with its prior explanations of its groundwater protection policy, or with its statutory responsibility to promulgate standards protective of public health and safety. In its 2001 Final Rule, EPA observed, "we consider ground water that is, or could be, drinking water to be the most valuable ground water resource. We believe that it deserves the highest level of protection." 66 Fed. Reg. at 32128. The groundwater protection rule "continues a longstanding Agency policy of protecting groundwater resources and the populations who may use such resources." 66 Fed. Reg. at 32106 (June 13, 2001); see also EPA, "Protecting the Nation's Groundwater: EPA's Strategy for the1990s," Part 197 Docket No. A-95-12, item V-A-13. The separate groundwater standard was designed to "protect the groundwater in the vicinity of Yucca Mountain to benefit the current and future residents of the area who could use this ground water as a resource for drinking water and other domestic, agricultural and commercial purposes." 66 Fed. Reg. at 32106.

To excuse its early termination of groundwater protection, EPA insists in the proposed rule that public health protection from groundwater releases will be accomplished by extending the *individual protection* standard through peak dose. 70 Fed. Reg. at 49024. But, as discussed above, EPA's post-10,000-year individual protection standard is grossly inadequate. Application of the proposed 350-millirem (1000-millirem mean equivalent) standard to protection of public health from releases to groundwater would create the *lowest* level of protection, by far, ever proposed by a regulator, and would be contrary to the Agency's overall pollution prevention policies.

EPA's explanation also cannot be reconciled with its responses to comments addressing earlier challenges to the separate groundwater standard. As EPA then explained, the individual protection standard is not a sufficient substitute for groundwater protection. EPA stated that the individual protection standard, which focuses specifically on human health,

> would address ground-water resources and the viability of ecological habitats less effectively than would separate groundwater protection standards. We believe that ground-water protection standards will confer greater protection to aquatic or biological communities by limiting the contamination of groundwater that would discharge to the surface, such as springs or seep areas.… We have a longstanding policy to encourage protection of groundwater resources in a consistent manner in our programs that may affect groundwater directly or indirectly.

Responses to Comment, 6-11, 6-12. As EPA counsel orally confirmed during the *NEI* litigation, EPA's separate groundwater standard "furthers the statutory goal of protecting public health and safety." January 14, 2004 Transcript at 59. And in *NEI*, as EPA correctly notes, the Court "concluded that [EPA's] reasoning for including such a standard as a means to protect the ground-water resource was sound and consistent with the Agency's overall pollution prevention policies." 70 Fed. Reg. at 49024.

In sum, EPA's refusal to entertain comment on its retention of the 10,000-year period for the groundwater standard is both unwise and unlawful. The 10,000-year termination period cannot be reconciled with the ruling in *NEI v. EPA*, and the arbitrary decision to abandon the standard at that stage is inconsistent with EPA's statutory and ethical obligations regarding environmental protection and public health.

Problems with EPA's Rationales for Its Standard

XIII. EPA Misunderstands the Importance of Uncertainty

The core justification EPA offers for numerous components of its proposed rule—its lax, two-tiered standard; its use of the median rather than the mean; and its attempts to pre-set modeling parameters, among others—is increased "uncertainty" after 10,000 years. But the EPA and DOE studies relied on by EPA show no qualitative increase in uncertainty after 10,000 years, and there is good reason to believe that the uncertainty after 10,000 years will in fact be less. Therefore, uncertainty provides no foundation for EPA's proposed rule. This contention is set forth in great detail in a report prepared for Nevada by Dr. M. C. Thorne, *The Role of Uncertainties in Defining the Proposed Standard* (Nov. 10, 2005), attached as Appendix C.

Moreover, it defies logic and common sense to use uncertainty about Yucca's future performance as a rationale for a *looser* standard. If DOE is highly uncertain about whether its chosen site and systems will be safe, that uncertainty provides more reason for retaining a conservative, protective standard through peak dose, not a looser one.

EPA's discussion of uncertainty is terminally vague, and fails to specify not only the logical link between uncertainty and a looser standard but also the types of uncertainty upon which EPA bases its logical leaps. Had EPA actually considered specific sources of uncertainty, it would have found that no source provides a basis for rationalizing a looser standard. Moreover, as the Court has already pointed out, EPA's uncertainty rationale is inconsistent with the NAS's findings and recommendations

Perhaps most importantly, there is no uncertainty about two key points: First, because DOE's containers will fail, and because the site geology allows water to flow through the repository, Yucca's radionuclides will eventually escape into the environment. Second, almost every projected scenario shows that when they do escape, the dose to the RMEI will sharply exceed 15 millirem/year. Thus, while EPA invokes uncertainty as a reason to escape a traditional 15 millirem standard, there is no real uncertainty about compliance with that standard; the site plainly flunks. EPA's uncertainty rationale therefore is nothing but a red herring. The reality is that EPA is seeking to escape from promulgating a standard it knows Yucca cannot meet. No public health rationale underlies its decision-making.

A. **<u>Illogic of EPA's Reliance on Generic "Uncertainty"</u>**

Even if EPA were correct that Yucca's long-term performance after 10,000 years is qualitatively more uncertain, its proposed rule fails to explain how that uncertainty justifies a more lax standard. Such an explanation would be extraordinarily difficult to provide, for the reasonable response to uncertainty about the safety of an engineered system would be to demand greater protection, or preclude that system from being deployed at all. Reasonable regulators never would evaluate the safety of bridges, for example, against less stringent safety standards simply because engineers were able to predict their performance only over the short-term. That uncertainty should only make regulators more conservative, not less.

Consistent with that principle, EPA (and other federal agencies) have until now reacted to anticipated uncertainty by adopting *conservative* assumptions and standards. In fact, Nevada has confirmed that, when faced with uncertainty, EPA uses conservative assumptions and adopts conservative standards in all areas of health-based regulation except, now, for Yucca. EPA does not explain why it departs from these sensible precedents.

For example, EPA adopted conservative values of parameters or standards when there were uncertainties when it regulated underground injection of hazardous materials under a regulatory regime (40 C.F.R .Part 148, especially 40 C.F.R. § 148.21(a)(5)) requiring that there be no migration of the wastes for so long as they remain hazardous, 69 Fed. Reg. 15328 (March 25, 2004); when it developed a methodology for deriving air quality criteria to protect health, 65 Fed. Reg. 66444 (November 3, 2000); when it regulated pesticides to protect health, 64 Fed. Reg. 37022 (July 8, 1999) ("the greater uncertainty in the data associated with the assumptions, the more conservative (i.e., unlikely to underestimate exposure) the assumptions should be"), and 68 Fed. Reg.

15945, April 2, 2003 ("uncertainty was addressed in the screening level assessments…with conservative assumptions for model inputs"); when it increased the cover standards to limit emissions from uranium mill tailings because of uncertainty in long-term (1000 year) projections, 48 Fed. Reg. 45926 (October 7, 1983); when it set water quality standards for toxic pollutants, 64 Fed. Reg. 61182 (November 9, 1999); when it developed a policy regarding persistent, bio-accumulation of new chemicals, 64 Fed. Reg. 60194 (November 4, 1999) ("given…the uncertainty…due to lack of data, the TSCA new chemicals program is and must be conservative by nature"); when it set emission standards for locomotives and locomotive engines, 63 Fed. Reg. 18978 (May 14, 1998); when it adopted principles for estimating neuro-toxicity in risk assessments, 59 Fed. Reg. 43260 (August 17, 1994); when it regulated hazardous wastes using the 90th percentile Monte Carlo risk curve, 63 Fed. Reg. 42110 (August 6, 1998); when it regulated food additives, 56 Fed. Reg. 7750 (February 25, 1991) ("in addressing uncertainties [in quantitative risk assessment] however, EPA generally uses conservative assumptions to ensure that risks are not underestimated."); when it protected drinking water, 56 Fed. Reg. 3526 (January 30, 1991); and when it listed hazardous wastes under RCRA, 55 Fed. Reg. 11798 (March 29, 1990).

Other federal agencies use similar approaches. For example, OSHA used the 95th percentile (as opposed to the central tendency) value in risk assessments used to derive safety standards for workers' exposure to toxic chemicals, 62 Fed. Reg. 1494 (January 10, 1997) (standards for methylene chloride). And HHS uses conservatisms in addressing health effects, 61 Fed. Reg. 33511 (June 27, 1996) ("a conservative (i.e., protective) approach to address these uncertainties in health effects").

In fact, EPA's abandonment of its longstanding approach to uncertainty has the effect of protecting humans in Nevada less than fish, for NOAA used conservative assumptions when confronted with uncertainty in protecting fish populations, 59 Fed. Reg. 7647 (February 16, 1994); 57 Fed. Reg. 3952 (February 3, 1992).

B. Unreasonably Vague Treatment of Uncertainty

While EPA repeatedly emphasizes "uncertainty" as a core justification for its proposed rule, its discussions of uncertainty are hopelessly vague. EPA uses the term "uncertainties" generically. It rarely specifies either the particular uncertainties with which it is actually concerned, or their likely effects, and it never coherently explains how it believes specific types of uncertainty might justify a more lax or a two-tiered standard. This is especially important when one considers that the most obvious source of potential uncertainty, climate change, as well as others, are eliminated from consideration.

This is a crucial failure. It precludes Nevada and others from knowing which uncertainty sources EPA considers important, and why EPA believes those sources might justify a higher standard. Indeed, EPA's failure to specify the relevant uncertainties suggests that EPA may not even know which uncertainties matter, or what the implications of particular sources of uncertainty actually are. Indeed, as noted earlier, premising a rule on uncertainties in the licensing analysis before the licensing analysis is even done is itself speculative to the point of being useless.

In lieu of specific discussion, EPA's proposed rule relies on inapposite analogies. EPA suggests that just as hurricane watchers cannot predict, several days in advance, where exactly a hurricane will strike and how damaging it will be, DOE will be unable to predict when peak dose will occur at Yucca Mountain. This analogy has some truth; because of major uncertainties about when its containers will fail, DOE does not know the timing of peak dose, and its projections that doses will increase only after 10,000 years are assumption-based modeling artifacts. But EPA misunderstands the relevance of its own analogy. Just as the Army Corps of Engineers should not measure levees against lax safety standards because it cannot predict exactly when Katrina-esque hurricanes will strike, Yucca Mountain should not be held to a looser standard simply because DOE cannot project when exactly the engineered barriers will fail. They will fail, and radionuclides will escape, at some time. EPA's standard must protect against that threat even if EPA and DOE are uncertain whether it will occur in 400 or 400,000 years.

The particular sources and types of uncertainty that exist at Yucca Mountain do have implications for regulatory decision-making. Some uncertainties imply that the site should be more carefully studied. Others imply the need for better engineering, or for a different site. *None* of these types of uncertainty provide any basis for a looser standard, or for taking a different approach to assessing post-10,000-year compliance. The report by Dr. Thorne establishes this fact. On a regulatory policy level, uncertainty about potential flaws in DOE's engineering barriers provides a reason for demanding better-engineered systems or, perhaps more realistically, for locating a site where geologic systems provide containment and thus mitigate the impact of the engineered barriers' inevitable failure, as is the case with DOE's WIPP repository site, for example. But it defies logic to suggest that DOE is entitled to a looser safety standard because it cannot say for certain whether its engineered systems will work.

The NAS was clear that reasonable predictions of the performance of the natural systems can be made within the period of geologic stability. But here too, DOE is not entitled to a looser safety standard simply because it is uncertain how its chosen site will behave because it stopped its site investigation program before all of the data were in. Also, some natural systems at the site will change in the future—for example, climate will vary, earthquakes may occur, and volcanic eruptions may disrupt the repository—and some uncertainties do exist with respect to such changes. The NAS considered possible uncertainties in natural system behavior and specifically concluded that they did not preclude assessments of performance at peak dose. It repeatedly rejected any suggestion that these parameters change and become more unpredictable at 10,000 years, noting that "earth scientists are accustomed to dealing with physical phenomena over long time scales." *Id.* at 71. But again, such uncertainties, even if they were more than NAS assessed, are no basis for setting a laxer standard. If Yucca were a better site, with much longer geologic containment, these uncertainties would matter much less or not at all. A poor site is no justification for a lax standard.

C. **EPA's Uncertainty Rationale is Inconsistent with the NAS's Recommendations**

EPA's reliance on "uncertainty" as justification for a two-tiered standard is also thoroughly inconsistent with the findings of the NAS. EPA's core rationale for its looser standard is that unspecified uncertainties render long-term compliance assessments less meaningful than those for shorter periods. In a typical statement, EPA writes that

> we also believe that over the very long periods leading up to the time of the peak dose, the uncertainties in projecting climatic and geologic conditions become extremely difficult to reliably predict and a technical consensus about their effects on projected performance in a licensing process would be difficult, or perhaps impossible, to achieve.

70 Fed. Reg. at 49029. Accordingly, EPA states that "in formulating an approach to compliance out to peak dose, we have established 10,000 years as an indicator for times when uncertainties in projecting performance are more manageable…." *Id.*

The NAS's findings, however, were to the contrary.[2] "Implicit in setting a Yucca Mountain standard," it concluded,

> is the assumption that EPA, USNRC, and DOE can, with some degree of confidence, assess the future performance of a repository system for time scales that are so long that experimental methods cannot be used to confirm directly predictions of the behavior of the system or even of its components. This premise raises the basic issue of whether scientifically justifiable analyses of repository behavior over many thousands of years in the future can be made. *We conclude that such analyses are possible*, within restrictions noted in this report.

NAS Report at 1 (emphasis added); *see also id.* at 55 (specifically rejecting increasing uncertainty as a reason for a different approach after 10,000 years); *id.* at 68. The NAS noted one specific restriction on that conclusion—its determination that future *human* scenarios were too uncertain to model—but otherwise adhered to the consistent conclusion that uncertainties did not preclude meaningful assessments of long-term compliance with a numeric standard. *Id.* And it expressly rejected any suggestion that 10,000 years represents a significant crossover point at which uncertainties render long-term compliance assessment less meaningful, finding that "there is no scientific basis for

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[2] In addition to being inconsistent with the findings and recommendations of the NAS, EPA's conclusions about steadily increasing uncertainty are wrong. Even if DOE is correct in its optimistic assumptions about short-term performance of the waste canisters, its current modeling graphs indicate that the range of modeling results rises initially but then *decreases* as time passes. *See* Appendix C. And if those engineering assumptions are acknowledged to be major sources of uncertainty, the highest levels of uncertainty are likely to occur even earlier.

limiting the time period of an individual-risk standard in this way." *Id.* at 6. The NAS report thus contains an unequivocal rejection of the notion that uncertainties are somehow more unmanageable in longer-term compliance projections.

Rather than acknowledging, let alone avoiding, this conflict, EPA attempts to mask it through disingenuous discussion of the NAS report. EPA quotes the NAS stating, "[b]ecause there is a continuing increase in uncertainty," and suggests that this carefully selected excerpt indicates that the NAS clearly agrees with EPA's view that "uncertainties generally increase with time, at least to the time of peak dose." 70 Fed. Reg. at 49025. But the entire NAS quote states: "Because there is a continuing increase in uncertainty about most of the parameters describing the repository system farther in the distant future, it might be expected that compliance of the repository in the near term could be assessed with more confidence. *This is not necessarily true.*" NAS Report at 72 (emphasis added). The NAS then explained why "this is not necessarily true," pointing out that many site parameters (like geologic parameters) do not change with time, and that others are more significant during the short term. *Id.*

EPA also attempts to mask its continued disagreement with the NAS by labeling its uncertainty rationale a mere matter of "policy," and by citing exceedingly general statements from the publications of other nuclear regulatory authorities. But the NAS's uncertainty-related determinations quite clearly were not policy determinations. The NAS instead considered those determinations, all of which relate to specific scientific issues like present and future geology, climate, and hydrology, to be well within the bounds of its scientific authority. EPA may disagree with those conclusions, but it may not escape the EnPA's mandate simply by attempting to characterize its technical disagreement with NAS as a "policy" dispute.

D. <u>Prior Judicial Rejection of Uncertainty Rationale</u>

In employing an uncertainty-based rationale directly at odds with the NAS's findings and recommendations, EPA has not only abrogated EnPA's mandate; it also has attempted to resurrect an approach already rejected by the Court. That attempt suggests that EPA does not realize, or is choosing not to acknowledge, that it is bound by a judicial decision.

Uncertainty was a key rationale for the portion of 40 C.F.R. Part 197 that the Court has already set aside. In attempting to justify its previous 10,000-year cutoff, EPA asserted, just as it asserts today, that "we have concerns regarding the uncertainties associated with such projections, and whether very long-term projections can be considered meaningful." 66 Fed. Reg. at 32096. It similarly stated that "[d]espite NAS's recommendation, we conclude that there is still considerable uncertainty as to whether current modeling capability allows development of computer models that will provide sufficiently meaningful and reliable projections over a time frame up to tens-of-thousands to hundreds-of-thousands of years." *Id.* at 32098. And it sought to cast a gloss of "policymaking" over those statements, asserting that "the selection of a compliance period for the individual protection standard involves both technical and policy considerations." *Id.*

EPA heavily relied on that "uncertainty" rationale in its arguments before the Court. It claimed that the 10,000-year cutoff was justified partly by "the large uncertainties inherent in attempting to project human exposures to releases from the repository for time periods over 10,000 years…." EPA Brief at 14, 19. And it provided a detailed discussion of these uncertainties, suggesting, in terms highly similar to those of the current proposed rule, that increasing uncertainties made long-term compliance projections untenable. *Id.* at 44-45. At oral argument, EPA's counsel clearly repeated EPA's attempt to cast this uncertainty rationale as a key policy judgment, arguing, in response to a question about the "policy aspects" of EPA's decision, that uncertainty was "one of the most significant" policy rationales for treating the post-10,000-year compliance assessment differently. Oral Argument Transcript, *NEI v. EPA*, at 25. EPA's current argument—that uncertainty justifies a different post-10,000 year standard—thus has already been considered and rejected by the Court.

The Court rejected EPA's 10,000-year cutoff and the uncertainty rationale upon which it purported to rest. 373 F.3d at 1270-73. Indeed, at oral argument, Judges Tatel and Edwards repeatedly indicated that they were well aware that EPA was trying to use uncertainty to justify its differing treatment of the post-10,000-year period and questioned EPA's discretion to employ that rationale. In a typical statement, Judge Tatel, responding to EPA's attempt to cast its uncertainty disagreement as a policy disagreement justifying its 10,000-year cutoff, said, "but that's the scientific judgment that Congress wanted the EPA to defer to." Transcript at 25. That transcript, the former rule, EPA's briefing, and the decision itself all indicate that EPA has already litigated its uncertainty rationale and lost. Accordingly, EPA is legally prohibited from resurrecting "uncertainty" as the core rationale for a permissive post-10,000-year standard.

XIV. EPA Misunderstands the Need for, and Absence of, Conservatism

The other core pillar of EPA's rationale for its proposed rule is its suggestion that analysis of the future performance of Yucca by DOE will be "overly conservative." EPA posits that DOE's models will be overly negative in their predictions of repository performance, and that EPA must therefore create a lax rule to accommodate or balance out that negativity.

Elsewhere in these comments, Nevada will explain that judgments about the conservatism of DOE's modeling—which has not yet been completed—are not EPA's to make. Here, Nevada focuses solely on the irrationality of relying on perceived over-conservatism as a rationale for a lax standard, explaining why EPA's reasoning is both flawed and lacking in empirical basis.

A. EPA's Failure to Explain Its "Over-Conservatism" Rationale

The first major problem with EPA's over-conservatism rationale is that EPA never explains it. EPA never describes the logical link between an overly conservative analysis and a more lax, second-tier standard. Nevada infers that EPA believes the standard must be lax to accommodate perceived weaknesses in the modeling, but EPA itself has never specified this or any other rationale. But even this rationale, if expressed, would be unreasonable, for the proper remedy for flawed modeling is to fix the modeling, not to weaken the standard. If EPA intended to say that, because of inevitable increased conservatisms after 10,000 years, a 350 millirem/year standard is the equivalent of 15 millirem/year, it has failed to support its premise. In fact, the opposite premise is the more supportable one. The report by Dr. Thorne in Appendix C confirms this.

In support of its statements about conservatism, EPA does cite a 2005 report prepared by its contractor, Cohen and Associates. But that report cannot support any proposition about the degree of conservatism in DOE's analysis. To evaluate whether DOE's past modeling was overly conservative, the report would have needed to determine which assumptions were conservative and which were optimistic. It would then have needed to quantitatively assess the relative importance of those assumptions to determine whether the overall results were shifted toward conservatism or optimism. Because some degree of conservatism normally is considered desirable in a risk projection—particularly where, as EPA repeatedly states is the case here, there is some uncertainty about the projections—EPA would also need to determine whether any resultant shifting of the projections was excessive.

The Cohen report contains no such analysis. Instead, it provides a qualitative and almost totally one-sided discussion. It summarizes almost every assumption that could conceivably be characterized as conservative, sometimes even double-counting the same assumptions. With the exception of a handful of pages (discussed in detail below) in chapter 5, however, the report does not even consider whether optimistic assumptions have been made. Moreover, nowhere does the report perform any quantitative analysis of the effects of the assumptions it identifies, let alone quantitatively address the effects of the optimistic assumptions it ignores. The report is thus like a legal analysis that addresses only one side of an argument; it is completely unbalanced and provides no basis for EPA to conclude that DOE's modeling is overly conservative. Moreover, the Cohen report fails to support the actual rule proposed by EPA which, as noted above, eliminates many uncertainties and potential conservatisms from the analysis.

B. A Bounding Approach is the Only Appropriate Approach

EPA's conservatism rationale founders for a second reason: EPA fails to explain why conservatism is inappropriate. To the extent conservatisms are unnecessary, and can be replaced by more realistic analyses, this is the appropriate solution – not weakening the standard. Indeed, by premising the rule on alleged conservatisms after 10,000 years, the rule has the perverse effect of discouraging DOE and NRC from doing more realistic analyses, lest the premise for application of EPA's rule be found lacking and the licensing process be thrown into confusion.

To the extent the state of scientific knowledge does not permit realistic analyses, then bounding assumptions and analyses are inevitable, but we have no way of knowing how such bounding assumptions and analyses are conservative. It defies scientific logic to give credit for "conservatisms" when it cannot be established whether the conservatisms actually exist. In fact, as discussed above, EPA traditionally considers conservatism an important and necessary response to this kind of uncertainty.

Such conservatism is particularly important for Yucca Mountain, because EPA's standard and NRC's licensing process will likely be the only opportunities to "test" the safety of the repository design. If DOE, EPA, and NRC eschew conservatism in their approval process and allow the construction of a repository with only a moderate probability of success, they will create a major risk for future generations—without giving those future generations any tools to manage that risk. Those future generations may not have any ability to undo repository failures, or even to know that the repository exists. A conservative standard now will be the primary protector of their safety.

C. <u>DOE's Analysis Will Not Be Conservative</u>

As noted above, the greatest uncertainty in the performance of the repository relates to the timing of the peak dose, which is itself entirely dependent on the lifetime of man-made waste packages. If DOE's optimistic assumptions about container life are wrong, then DOE's entire performance evaluation becomes extremely non-conservative. EPA itself has noted the importance of this issue, which, if DOE's assumption is wrong, has led modelers to vastly overestimate the ability of the repository to contain waste.

There is no disagreement that DOE's waste containers eventually will inevitably fail, and that Yucca's porous geology will permit leaking radionuclides to reach the accessible environment. The timing of that failure is uncertain, for DOE is proposing to employ engineered systems that have never been tested on anything approaching the time scales over which DOE hopes they will provide protection. Finally, there is no genuine dispute that the resistance—or lack thereof—of the containers to corrosion is the crucially important determinant of the timing of peak dose.

In its recent report, EPA's contractor provided a detailed discussion of DOE's lack of knowledge about when its containers will fail. Initially, the Cohen report noted that DOE's proposed system is unique. "Unlike most concepts adopted by other nations," it stated, "the proposed Yucca Mountain repository exposes the metallic waste packages and drip shields to sustained oxidizing conditions." Cohen at 5-1. It then noted that the performance of that unique system was difficult to predict. "Engineering experience," the report stated, "with passive metals is extremely short (i.e., approximately 100-150 years) compared with the timeframe of repository performance projections. Extrapolation of present knowledge to the longer timeframe is thus highly uncertain." *Id.* at 5-13 (parentheses in original). It later added that "[t]he failure, to date, to identify clear natural or archeological analogs for long-term passive metallic behavior seriously limits confidence regarding the stability of passive films in providing extremely long-term corrosion resistance." *Id*. at 5-15.

In drawing these conclusions, the Cohen report cited, and followed, the conclusions of leading corrosion experts. In 2001, an expert panel considered corrosion risks to the Yucca Mountain containers. That panel "called attention to how little is presently known about the nature of passive film on Alloy 22," the alloy to be used to provide corrosion resistance for containers at Yucca Mountain, and it considered a series of ways in which the containers might fail. *See id.* at 5-15 to 5-16 (quoting Sagues, 2002).

The Cohen report also emphasized the threat of unanticipated modes of corrosion. "[U]nexpected modes of alloy deterioration often emerge when service conditions deviate (even on a microscopic scale) from anticipated regimes," it wrote, and it concluded that "the possibility of other unexpected but potentially severe deterioration mechanisms developing into the far future cannot be dismissed easily." *Id.* at 5-13 (parentheses in original). The expert review on which the Cohen report relied similarly identified a series of potential failure modes that would merit further study.

In addition to being highly uncertain, the corrosion resistance of the casks is critically important. The Cohen report notes that "the choice of corrosion rates for the performance projections is a major factor in both estimating the magnitude and time of peak dose projections." Cohen at A-20. EPA similarly emphasizes that corrosion is "exactly the critical element in estimating the timing and magnitude of peak dose." 70 Fed. Reg. at 49026. This importance exists for an obvious reason; because water always is percolating through Yucca Mountain, radionuclide transport will begin as soon as radionuclides are released, and corrosion rates therefore will determine when releases take place. Indeed, the effect of those corrosion rates on repository performance is so great that EPA's own economic impact analysis suggests that there is little value in attempting to reduce any other sources of uncertainty. Cohen at A-20.

EPA's own documents thus indicate (1) that the rate of corrosion is of enormous importance; and (2) that EPA and DOE have very little certainty about how quickly corrosion will occur. Nevertheless, DOE's models, to date, consistently have assumed that no corrosion-related failure will occur during the first 10,000 years of the repository lifetime, and, indeed, that robust corrosion resistance will continue for additional thousands of years. *DOE thus has assumed the certain performance of one of the most uncertain aspects of the repository system*.

This assumption undermines EPA's speculative theory that DOE's modeling will be "overly conservative." DOE has made highly optimistic assumptions about the single most critical variable affecting repository performance, notwithstanding the "various sources of worse-than-anticipated performance of the WP that have not been sufficiently investigated, or, in some instances, would be very difficult to evaluate in a short research period." Cohen at 5-16. That assumption leaves DOE's analysis as optimistic as a safety assessment of the Titanic that assumed the ship certainly would not collide with icebergs, or an analysis of the Hindenburg's safety that ignored the potential proximity of sparks.

Moreover, corrosion assumptions are just one of many potential sources of optimism in DOE's proposed modeling. Neither DOE nor EPA has done a comprehensive analysis of optimistic assumptions and their potential consequences, but, as discussed in detail elsewhere in these comments, several other assumptions and modeling techniques could similarly skew the analysis. For example, EPA's proposed exclusions of criticality events, EPA's ratification of DOE's assumption of the non-existence of manufacturing defects, EPA's exclusion of natural events it considers "unlikely," and EPA's exclusion of localized corrosion and other potential engineering problems all would skew DOE's modeling toward potentially excessive optimism. *See* discussion *infra* on FEPs. That excessive optimism vitiates any attempt by EPA to rely on supposed "over-conservatism" as a justification for a lax second-tier standard.

XV. EPA Misuses Natural Background

EPA's proposed rule offers a convoluted and arbitrary rationale for what its second-tier standard should be. EPA suggests that "given the large uncertainties surrounding the outcomes at these unprecedented time frames," it is reasonable to set a standard based on natural background radiation levels in one of the nation's more radioactive states: not Nevada, where Yucca Mountain actually is, but Colorado. On this rationale, EPA concludes that allowing 350 millirem/year of anthropogenic exposures to Nevada's citizens is appropriate. But for a series of reasons, EPA's background rationale is fatally flawed.

A. EPA's Natural Background Rationale is Inconsistent with EPA's Own Past Conclusions and NAS's Recommendations

First and foremost, EPA's Colorado rationale is flatly inconsistent with EPA's past standards and conclusions, and with the NAS's recommendations. Although EPA has been regulating anthropogenic radiation exposures for decades, it has never used this type of standard or invoked this natural background rationale before. Instead, its consistent past practice has been to follow the international consensus and allow a maximum of 100 millirem/year of anthropogenic exposures *from all sources combined*, and to allow individual sources to contribute no more than 15 millirem/year of exposure, a level it noted was consistent with the NAS's recommendations (a range of 2 to 20), and that EPA continues to assert is appropriate for Yucca Mountain in the pre-10,000-year period. 66 Fed. Reg. at 32088 (15 millirem/year is "within the NAS-recommended range"); *see* NAS Report at 41 (describing the international consensus supporting this level). EPA has viewed the 15 millirem/year level of protection as consistent with the specific recommendations of the NAS report.

In soundly rejecting suggested 25 millirem, 70 millirem, and 150 millirem standards, EPA never even hinted that existing natural background levels in other places somehow would have made those higher levels appropriate. *See* EPA Response to

Comments at 4-5 to 4-6. Instead, EPA has taken the consistent position that 15 millirems is the reasonable limit on anthropogenic exposure from one source. Likewise, where the NAS spoke of natural background as a benchmark for acceptable exposures, it referred only to the "concept of negligible incremental dose (above background levels)," a concept that suggests that repositories should cause negligible incremental changes—not a doubling—of existing background levels. *See* NAS Report at 8-9 (parentheses in original).

EPA's proposed rule never comes to terms with this sharp divergence from its past practice. At most, EPA insinuates that international bodies support its new notion that anthropogenic sources should be able to double existing natural background levels. But in fact they do not. EPA's citations are misleading and out of context. See Appendix A. As EPA itself noted, "[n]o regulatory body that we are aware of considers doses of 150 mrem to be acceptable," and those international bodies have never suggested that natural background levels should create an exception to the more stringent limits they have created. EPA, Response to Comments at 3-8.

There is good reason for EPA's (and other standard setting agencies') past reluctance to use natural background or variations in natural background as a basis to establishing acceptable levels of risk. A risk is not acceptable just because it is "natural." Societies undertake extraordinary measures to eliminate or mitigate such natural hazards as hurricanes, tornados, and toxic substances found in nature like botulism. Moreover, the concept that variations in natural background pose acceptable risks is based on the highly doubtful premise that people are knowledgeable about these radiation levels, and the associated health effects of radiation, when they choose where to live or work. Finally, even if these comparisons were relevant, EPA cannot explain how they are uniquely relevant to the period after 10,000 years.

B. <u>EPA's Colorado Rationale is Irrational and Inconsistent with Past Practice and NAS's Recommendations</u>

Discerning how the Colorado rationale is actually supposed to justify EPA's proposed standard is not easy, for EPA's explanation of the rationale is far from clear. EPA never performs any kind of risk assessment that concludes that a 700 millirem total exposure is safe. Nor does it ever suggest that the fact that people's choices to live in Colorado reflect a societal judgment that such exposure levels are safe; EPA specifically states that "[i]t should be clear that we are not arguing that most people take into account levels of background radiation when deciding where to live or work, or that it in any way plays a major role in their decision-making." 70 Fed. Reg. at 49038. Instead, EPA reasons that since levels of exposure near 700 millirem/year occur naturally in a few isolated places, and people live in those areas without obviously dying in droves, a standard that allows 350 millirem/year anthropogenic exposure on top of the already occurring 350 millirem/year of natural exposures in the Amargosa Valley must suffice. As EPA puts it, risk levels apparently are fine so long as "in EPA's view" those levels "do not 'pose a realistic threat of irreversible harm or catastrophic consequences.'" *Id.*

EPA does not explain why it holds this view. But the rationale is in any event arbitrary. EPA's role is to establish a standard protective of public health and safety, and never in the past has it considered that role to be fulfilled merely through avoidance of "a realistic threat of irreversible harm or catastrophic consequences." Instead, it has set standards, both to protect people from radiation and in other regulatory contexts, designed to allow only the most minimal of increases in the levels of cancer and other illnesses already induced by background levels of radiation.

Moreover, EPA itself has acknowledged, as has the NAS, the general consensus views that natural background radiation levels are not "safe." The NAS noted that "[i]nternational scientific bodies currently accept what is called the linear, or no-threshold hypothesis for the dose-response relationship… . The no-threshold hypothesis holds that there is no dose, no matter how small, that does not have the potential for causing health effects." In its original 40 C.F.R. Part 197 rule, EPA, after discussing research on the health risks of radiation exposures, similarly noted that even natural background levels cause human harm. "We believe," EPA stated, "that the best approach is to assume that the risk of cancer increases linearly *starting at zero dose*. In other words, any increase in exposure to ionizing radiation results in a constant and proportionate risk in the potential for developing cancer." 66 Fed. Reg. at 32080-81 (emphasis added). EPA specifically noted that the risk of anthropogenic radiation could not be considered in isolation, but instead must be considered in addition to the pre-existing risks created by background conditions. "The risk of interest," EPA stated, "is not at or near zero dose, but that due to small increments of dose above the pre-existing background level." *Id.* at 32080 n.6. It is for this reason that EPA in the past has always sought to keep anthropogenic exposures at levels well below background levels; it has respected the scientific consensus that even background levels kill. *See also* EPA, *A Citizen's guide to Radon*, OAR-2005-0083-0058, at 2 (noting that background levels of radon kill an estimated 21,000 Americans every year, and that radon is a larger source of death than drunk driving).

Similarly, EPA's implication that it can safely create Colorado-like levels of exposure in Nevada because people live in Colorado is untenable.[3] Simply because a risk exists naturally in one location does not mean that it is acceptable or "safe" for humans to create it somewhere else. We would never accept as "safe" a human project that creates San-Francisco-like levels of earthquake risk in Chicago, or that subjects Washington D.C. to the risks of hurricane damage that Miami naturally faces, even though millions of people live in the at-risk areas. Similarly, EPA has no basis in implying that because people live in Colorado now, the radiation levels they may face may acceptably be created elsewhere.

In setting other health and safety standards, EPA has frequently rejected

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[3] This also is only an implication; EPA is never brazen enough to expressly state this rationale. But its invocation of the Colorado rationale clearly appears designed to foster the impression, even if EPA attempts to disclaim this rationale, that future Nevadans will be safe because they will face risks already allegedly borne by some Coloradans.

comparisons with natural background. Earlier this year, EPA rejected the concept that emissions of hazardous materials should not be regulated if the resulting levels in the environment are within the bands of variation in ambient background levels. 70 Fed. Reg. 19992, April 15, 2005 (rule limiting emissions from coke oven batteries), citing with approval 54 Fed. Reg. 38044, September 14, 1989 (rule limiting emissions of benzene and other hazardous materials). EPA also rejected a natural background radiation rationale when it set health-based emission standards for radioactive materials under a statutory regime (the Clean Air Act) identical to the Atomic Energy Act, 54 Fed. Reg. 51654, December 15, 1989, and when it set standards limiting radioactive emissions from uranium mills, 51 Fed. Reg. 42573, November 2, 1986. Notably, EPA rejected comparisons with natural background when it proposed changes in guidance to all federal agencies on the formulation of radiation protection standards. 66 Fed. Reg. 66414, December 23, 1994 ("although the average level of exposure to natural background provides perspective, it does not, however, provide justification for the RPG [Radiation Protection Guidance], since it represents an uncontrollable source of risk, and the RPG applies to controllable sources").[4]

Additionally, EPA's rationale misunderstands the role of radon in creating natural exposures in Colorado and elsewhere. As EPA acknowledges, most natural exposures, in Colorado and elsewhere, result from radon. Indeed, in Colorado radon accounts for approximately 87% of total radiation exposure. S. Cohen and Associates, *Assessment of Variations of Radiation Exposure in the United States* (2005), OAR-2005-0083-0077, at 4. But radon exposures are locally variable, site-specific, and amenable to mitigation; a person lives with radon risk because either they are ignorant of that risk or they have made a conscious choice not to deal with it.

C. <u>EPA's Selection of Colorado as Its Benchmark is Arbitrary</u>

Independently of the errors discussed above, EPA's method of choosing its natural background benchmark is irrational. If EPA were to utilize a natural background standard, the most logical benchmark for that standard would be natural levels in the Yucca Mountain area or, perhaps, in the nation as a whole, which has average radiation levels significantly lower than those that already exist in the Amargosa Valley.[5] But EPA has deliberately rejected both possibilities, and has chosen Colorado for two simple reasons: first, because Colorado has substantially higher natural background radiation

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[4] In its proposed rule, EPA concedes that "meaningful distinctions are made today between natural background radiation and additional incremental (and involuntary) exposures caused by human activity." 70 Fed. Reg. at 49039. Without offering any explanation, EPA asserts that those distinctions somehow become irrelevant over longer time frames.

[5] If EPA believes natural background levels provide an appropriate benchmark for the total level of risk from all sources of radiation, the repository should not be located in Nevada *at all*, for Nevada already has higher-than-the-national-average risk levels.

than the Amargosa Valley or the country as a whole; and second, because Colorado also is in the western United States.

EPA's reliance on the former reason is completely circular. In effect, EPA has determined that increased radiation is appropriate by comparing conditions in the Amargosa Valley to a subset of other states, all of which it selected specifically because they have higher exposure levels, and within that subset has chosen Colorado over Idaho apparently just because Colorado is more radioactive. EPA thus based its conclusion that higher exposure levels are allowable on the premise that its analysis must produce a conclusion that higher exposure levels are allowable. Put differently, EPA has proposed that Nevada can have substantially higher exposure levels because Colorado does, and has said that Colorado is an appropriate comparison because it has substantially higher exposure levels. This reasoning lacks any logic. Comparing Nevada to Colorado because both are in the West, and therefore determining that Colorado's natural background levels are appropriate for Nevada, is as reasonable as suggesting that humans could appropriately recreate New Orleans' flood risk in Atlanta because both are in the South.

EPA has provided no other reason for its selection of Colorado. That selection therefore appears to represent an obvious effort by EPA to rig its analysis, and to justify its predetermined conclusion that an unprecedentedly high standard should be employed.

D. EPA Use of Natural Background Wrongly Assumes Natural Risks are Acceptable

As the report by Dr. Fleming in Appendix D establishes, EPA cannot assume that natural background or variations in natural background are acceptable risks. Yet this appears to the basis for EPA’s proposal.

XVI. EPA Abandons Intergenerational Equity

Having incorrectly determined that "uncertainty" renders impossible a traditional, apportioned standard, EPA proposes that it needs an alternative, and that 350 millirem/year is acceptable as a putative "policy" choice. But EPA offers no real explanation of why 350 millirem/year, which EPA does not consider acceptable today or 10,000 years from now, should be considered acceptable after 10,000 years. EPA hints that principles of intergenerational equity somehow support its proposed rule, but for a series of reasons, that implication is illogical, unjustified, and ethically wrong.

These flaws are explained in detail in Appendix D, a white paper prepared by Professor Patricia Ann Fleming, Ph.D. Dr. Fleming's full report must be considered. She considers the ethical implications of EPA's proposed action and the ethical rationales EPA has stated, or implied, in support of that rule, and concludes that EPA misconstrues accepted principles of intergenerational ethics, mischaracterizes the sources upon which it relies, and has offered an incomplete and internally inconsistent ethical rationale. Nevada incorporates Dr. Fleming's paper, in its entirety, by reference into these comments.

A. Vagueness

Initially, EPA's discussion of intergenerational equity is fatally vague. EPA never actually states what equitable principle it is adopting. Instead, EPA's proposed rule provides a cursory, selective, and inaccurate survey discussion of a few intergenerational equity theories, none of which EPA itself has ever adopted in the past. *See* Appendix D (discussing EPA's selective use of sources and its mischaracterization of the limited set of sources it does cite). EPA then hints at the notion that an action is equitable so long as it does not impose catastrophic burdens upon future generations. EPA never clearly articulates the principle it is endorsing, let alone explains why EPA considers that particular principle to be just, equitable, or appropriate. That failure of explanation leaves intergenerational equity as an improper basis for EPA's rule, for EPA cannot merely hint that a policy justification for its proposed action *might* exist; it must actually articulate and support its purported policy rationale.

B. Inconsistency with Past Statements and Policies and Relevant Law

EPA's failure of explanation stands in sharp contrast to its prior Yucca rule, in which EPA clearly articulated the "fundamental principle of intergenerational equity" that "we should not knowingly impose burdens on future generations we ourselves are not willing to assume." 66 Fed. Reg. at 32107. EPA does not explain whether it is abandoning this "fundamental principle" now, or how its proposed rule, which quite clearly does impose additional burdens on future generations, could possibly be reconciled with this "fundamental principle."

EPA's proposed rule is similarly suspect in light of the NWPA, which requires protection for future generations. In the NWPA, Congress stated that "appropriate precautions must be taken to ensure that such waste and spent fuel do not adversely affect the public health and safety and the environment for this or future generations." NWPA § 111(a)(7). This Congressional statement supports EPA's erstwhile "fundamental principle" that "we should not knowingly impose burdens on future generations that we ourselves are not willing to assume." 66 Fed. Reg. at 32107. But it is irreconcilable with EPA's current proposal to subject future generations to burdens that current generations have never deemed acceptable. Congress's statement is similarly inconsistent with any implication that future generations need not be accorded protection and ethical standing.

EPA's proposed rule also violated the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, to which the United States has agreed. That convention provides that contracting parties shall take appropriate steps to "strive to avoid actions that impose reasonably predictable impacts on future generations greater than those permitted for the current generation."[6] Section 101 of the National Environmental Policy Act has similar language in its declaration of a

[6] *See* http://www.iaea.org/Publications/Documents/Conventions/jointconv.html (last checked November 7, 2005).

national environmental policy. The EPA rule reflects no such effort. It instead is predicated on an unlawful repudiation of this principle, for it would *purposefully* "impose reasonably predictable impacts on future generations greater than those permitted for the current generation."

The EPA rule is also contrary to one of the key IAEA "Principles of Radioactive Waste Management" (IAEA 1995), agreed to by the United States, that "radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today." EPA offers no reason why the United States should change its policy now with respect to Yucca and Nevadans. Nor does it have the authority to set or change U.S. policy in this regard; its sole duty here was to set a health-based standard that would protect this *and* future generations.

C. EPA's Implied Principle Misunderstands Intergenerational Equity

EPA's proposed rule also reflects a basic philosophical misunderstanding of intergenerational equity. Principles of intergenerational equity traditionally have been designed to *protect* future generations from unfairly bearing the burdens of current generations' activities. For example, EPA stated that "we should not knowingly impose burdens on future generations that we ourselves are not willing to assume." 66 Fed. Reg. at 32107; *see also* Appendix D. Yet EPA apparently would turn that notion on its head, implying that intergenerational equity is a *justification for*, rather than a bar to, subjecting future generations to burdens that our generation has never been willing to impose upon itself. In the name of intergenerational equity, EPA suggests that it may appropriately impose contamination levels beyond anything our generation accepts for itself, and to do so for a period that is orders of magnitude longer than the entire history of human civilization. *See* Figure 1, *supra* (graph showing the duration of the period of *median* doses close to 350 millirem/year); *compare* EPA, Response to Comments at 3-8 (2001) ("no regulatory body we are aware of considers doses of 150 mrem to be acceptable") (emphasis added). This is as rational as invoking the Christian Golden Rule to justify theft.

Indeed, as discussed in detail by Professor Fleming, the traditional premise of nuclear waste regulation has been that current generations do owe duties to future generations, and that those future generations should not suffer harms greater than those risked by the generations that actually derive the benefits from nuclear activities. Intergenerational equity is a constraint, not a license for current regulators to do whatever they please.

Even the obscure sources[7] EPA selectively cites cannot sustain its implied contrary theory. *See* Appendix D (characterizing EPA's choice of sources as "cherry-

[7] Notably, EPA never explains why it needs to rely on these sources when past U.S. and EPA policy is clearly contrary to these sources—or, at least, is contrary to EPA's crabbed interpretation of these sources.

picking"). First, the National Academy of Public Administration ("NAPA") report does not support EPA. That report recommends a "sustainability principle" that "no generation should deprive future generations of the opportunity for a quality of life comparable to its own." While the report also recommends that "each generation's primary obligation is to provide for the needs of the living and next succeeding generations" and that "near-term hazards have priority over long term hypothetical hazards," these recommendations are premised on the need to avoid trade-offs where present generations suffer an injustice, and on the concept of a "rolling present" which requires each generation to provide the next with the opportunity to reevaluate decisions and make changes. EPA never explains how its proposed two-tiered standard can be reconciled with those principles, and indeed it could not. EPA has identified no injustice the present generation would suffer were EPA's standard consistent, and thus NAPA's former premise for favoring current generations does not exist. Nor can EPA provide any opportunity for future generations to revisit the burdens EPA now proposes to impose, and thus the ability to create a "rolling present" does not exist.

EPA's other key source—a 1998 document by the Swedish National Council for Nuclear Waste ("KASAM")—contains none of the propositions for which it is cited. Indeed, in response to questions from Nevada regarding where in KASAM's report any of these statements existed, EPA conceded that they did not exist, and advised that the relevant comments instead came from another Swedish paper published in 2004 that is not yet publicly available in English. EPA then provided Nevada with an English-language translation of only one chapter of that document (chapter 9), which EPA claims supports its position.

Read in context, neither Chapter 9 nor the full 2004 Swedish document[8] even remotely supports EPA's proposed action.[9] Chapter 9 does describe a "minimal principle of justice"—as Appendix D points out, it is apparently the only discussion of that

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[8] Nevada subsequently itself located the entire document, translated into English, at http://www.sweden.gov.se/sb/d/574/a/52563.

[9] Moreover, key reference sources relied upon in KASAM's 2004 paper offer analyses that are fundamentally incompatible with EPA's approach to intergenerational responsibility in its proposed rule. For example, John Rawls' *A Theory of Justice* (1971) rejects any time preference that would dilute the moral responsibility to future generations; his discussion of justice between generations posits that "[n]o generation has stronger claims than any other." *Id*. at 289. *See also* Appendix D; KASAM 2004 document at 441-445 (discussing Rawls' work). KASAM also draws from works by Kristin Shrader-Frechette that have emphasized the present duty to avoid harm in the future. *Id.* at 449. In her most recent article, Dr. Shrader-Frechette expressly criticized EPA's new Yucca rule due to its failure to protect the life and health of future generations. Kristin Schrader-Frechette, *Mortgaging the Future: Dumping Ethics with Nuclear Waste*, 11 Science and Engineering Ethics (2005, Issue 4), at 3.

purported minimal principle—but the principle, as stated, does not support EPA's theory at all. Instead, the authors state that

> If we accept the minimal principle of justice as a reasonable principle for environmental ethics, it will have clear consequences for the nuclear waste issue. Thus, we are obliged to use nuclear power today in a manner that does not harm future generations—even if those generations are very distant. We cannot escape from our obligations just because they have to do with the very long-term consequences of our actions.

OAR-2005-0083-0197, at 429.

> The Principle of Minimal Justice applies for an unforeseeable period of time in the future and, quite simply, means that as long as living creatures exist on this planet, we have an obligation to not do anything that today that could jeopardise their life and health in the future.

Id. at 445.

> …Therefore, on the basis of this principle, the specification for the repository should be completely clear: We must build a repository that can protection [sic] human beings and other living organisms for hundreds of thousands of years into the future – or for as long as we can anticipate that the waste is hazardous.

Id. at 446.

> Paradoxically, uncertainty concerning the future state of society, technology and knowledge clearly provides us with clear guidance for how we, today, must design a repository in a morally responsible manner. *It must be designed so that, without controls and corrective measures, it can protect the human beings who will live in its vicinity from about the year 2050 and a couple of hundred of thousand years in the future*.

Id. at 447 (italics in original.)

> The Principle of Minimal Justice requires that, with our technology, we do not jeopardise future generations' possibilities for life. *First and foremost: Do no harm. This means that we should only construct a repository if we know that it is safe enough to protect future generations.*

Id. at 449.

This discussion is impossible to reconcile with the principle EPA purports to extract from this document. The authors quite clearly do not believe that current regulators have license to do whatever they please so long as they do not compromise future generations' prospect for survival. Instead, they state that any repository must "do no harm" "for as long as we can anticipate that the waste is hazardous." *Id.*

The remaining sources EPA cites also provide no support for its implied but unarticulated intergenerational equity position. For example, EPA cites several sources for the principle that long-term numeric projections are of less value, and implies that these somehow bolster its suggested theories of intergenerational equity.[10] Those general statements, however, do not rebut the clear findings of the NAS that long-term numeric projections for Yucca Mountain will have value and should be the proper basis for a compliance assessment. Indeed, several of the sources EPA cites suggest that numeric assessment is inappropriate only in post-*million*-year time periods—a proposition irrelevant to EPA's current decisions about assessing compliance in the post-10,000-year period. And even the 2004 KASAM report Chapter 9, from which EPA purports to extract a highly permissive principle of intergenerational ethics, is clear: "To refrain from long-term assessments on account of the difficulty of making them can never be considered to be a reasonable level of ambition." *Id.* at 446 (quoting KASAM, Nuclear Waste – Research and Technique Development 32 (2002).

D. <u>EPA Never Explains Why Its Implied Principle Applies to Yucca</u>

EPA's intergenerational equity rationale, to the extent that it exists, fails for an important additional reason: EPA has never explained how a lax second-tier standard benefits anyone. While EPA's entire theory appears to be that providing future generations with the same protection we provide ourselves today would impose burdens upon present generations, EPA has not stated what those burdens are. Indeed, it has identified *no* possible trade-off that will result in any present harm if current levels of acceptable risk are sustained after 10,000 years.

If EPA is implicitly suggesting that the benefit to this generation from the lax future standard is the present success of Yucca Mountain, it strays into impermissible territory, for EPA has no authority to pre-determine that the Yucca Mountain repository

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[10] EPA selectively quotes from a recent book that borrows from economics to suggest that future interests may be discounted in favor of present interests. N. CHAPMAN AND C. MCCOMBIE, PRINCIPLES AND STANDARDS FOR THE DISPOSAL OF LONG-LIVED RADIOACTIVE WASTES (2003). That discussion neglects the strong agreement among environmental economists and ethicists, as well as KASAM and the NAPA panel, that it is unacceptable to discount future generations' interests simply because they will live at a different time. *See* Appendix D. Moreover, read in context, Chapman and McCombie's analysis provides no real support for the proposed rule. Much like the NAS Report, they suggest that "[t[here are no real scientific grounds for specifying any specific time cut-off for either safety assessments or regulations, beyond which there is no requirement to consider the fate of the repository. In particular, *any cut-off imposed whilst calculated releases are increasing has no credibility.*" Chapman and McCombie, *op cit.,* at 79 (emphasis added), OAR-2005-0083-0061.

should be built regardless of health and safety threats. With the NWPA and EnPA, Congress gave EPA one duty—to set the health-based radiation standard for Yucca. It did not call upon EPA to evaluate whether the success of the nation's repository program at Yucca today can justify a weaker standard of care for future generations. EnPA section 801(a)(1) requires EPA to promulgate a "public health and safety standard for protection of the public from releases [from Yucca]." Section 801(a)(2) refers to this standard as "health-based." A "public health and safety" or "health based" standard must be based on a consideration of what is an acceptable level of risk; it may not be based on economic costs or a balancing of costs and benefits. *National Cottonseed Products Ass'n v. Brock*, 825 F.2d 482 (D.C. Cir. 1987) (citing *American Textile Manufacturers Ins't v. Donovan*, 452 U.S. 490 (1981)); *NRDC v. EPA*, 824 F.2d 1146 (D.C. Cir. 1987); *Union of Concerned Scientists v. NRC*, 824 F.2d 108 (D.C. Cir. 1987).

Moreover, Nevada disputes whether Yucca Mountain would actually provide any benefit to present generations. As Nevada has pointed out in detailed past comments, both the site itself and, potentially more importantly, the massive project of transporting 70,000 tons of nuclear waste across the country to the site pose enormous risks to present generations. *See* Nevada, *Comments on Department of Energy's Draft EIS*.

Similarly, a lax second-tier standard provides significantly reduced protection to generations living within the 10,000-year period. If the repository is licensed on the *assumption* that peak dose will occur after 10,000 years, and that assumption proves wrong, the first-tier standard will provide no protection to the people who bear the brunt of the repository's impacts. Instead, those generations, whom EPA has never suggested should receive the same minimal protection it would accord to generations in the post-10,000-year period, would be put at greater risk by EPA's decision to rationalize a lax-second-tier standard on the theory that later harms are somehow more permissible.

XVII. <u>EPA Wrongly Defines and Applies "Implementability"</u>

EPA's final justification for its rule is the euphemistic concept, originated by DOE, of so-called "implementability." EPA believes, reasonably enough, that the standard it selects should be usable by the NRC to distinguish an adequate repository design and site proposal from an inadequate one. But EPA offers no proof that its proposal will accomplish this result.

A standard must be "implementable" in the sense that the application of the principles of sound science should enable a regulator to decide whether or not compliance is achieved. But EPA's conclusion that only a lax standard is "implementable" in this sense is inconsistent with the findings and recommendations of the NAS. The NAS clearly determined that EPA's standard should apply at peak dose, and that physical processes affecting the site were sufficiently predictable to allow such a peak-dose compliance assessment. As EPA itself previously recognized, NAS recommended a methodology for setting the standard, and that methodology would produce dose limits in the 15 millirem/year range. *See* EPA, Response to Comments at 4-5 to 4-6 (rejecting a 70 millirem/year standard because it would be "well above the

NAS-recommended level"). Those determinations clearly indicate that, in the NAS's view, a 15 millirem/year standard is "implementable."

Moreover, EPA has produced nothing but speculation to suggest that only a higher standard is "implementable." Nor could it, for DOE's current modeling results show a clear and certain *failure*, by almost any statistical measure, when compliance is measured against a consistent 15 millirem standard. *See* TSPA graph reproduced in Appendix C) (showing that at peak dose, almost 100% of the model runs predict doses exceeding 15 millirem/year). Any test that shows such certain failure obviously would be implementable; NRC quite clearly can determine what the outcome would be.

To escape this obvious problem with its implementability rationale, EPA vaguely implies, notwithstanding the NAS's clear determinations, that inherent uncertainties would make compliance with a 15 millirem/year standard difficult at any site, and that a 15 millirem standard therefore is not "implementable" because it cannot distinguish good sites from bad. Yet EPA supplies absolutely no empirical support for this speculative statement.

EPA's "implementability" rationale is suspect for another reason: it already has been rejected by the Court. As the court noted, EPA's core rationale for its prior 10,000-year cutoff was that post-10,000-year analyses were "not practical for regulatory decisionmaking." *NEI*, 373 F.3d at 1268 (quoting 66 Fed. Reg. at 32097). EPA had reached this conclusion after considering "comment on whether it is possible to implement the NAS-recommended compliance period…." EPA's conclusion was that it was not. The Court specifically rejected this rationale, concluding that it was inconsistent with the NAS report. As the court noted, NAS specifically warned against calculational approaches that make "compliance rather easy" and "simplify licensing," but fail to uphold the core duty to ensure "no unreasonable risk to the health and safety of the public." 373 F.3d at 1271. Yet, EPA now proposes to resurrect a similar rationale to severely loosen its peak dose standard.

As discussed *infra*, what EPA really means by "implementability" is that DOE is entitled to a standard that Yucca can pass. But that determination is not EPA's to make. It is charged with promulgating a standard that protects public health and safety, and must do so consistent with the findings and recommendations of the NAS. It may not flout those recommendations and deviate from thirty years of practice by invoking "implementability" as an excuse to promulgate what is, in effect, a best available or best practicable technology standard, rather than a health-based standard, so as to grant Yucca an easy pass.

Problems with the Rule Other than the Standard

Like any administrative agency, EPA may not exceed the authority Congress has delegated to it. Here, EPA's authority is limited; it may only set health and safety standards for Yucca Mountain. Yet, EPA's proposed rule does far more than just set a standard. In numerous ways, those extra components of EPA's proposed rule would usurp the NRC's Congressionally defined role of resolving adjudicatory facts and making a licensing decision.

In addition to these usurpations of authority, EPA also proposes, without any Congressional authorization, to delegate part of its own rulemaking authority to the NRC.

XVIII. EPA's Effort to Legislate FEPs is Technically and Legally Flawed

EPA's proposed rule specifies several features, events, and processes (FEPs) that DOE is to model, or is to specifically avoid modeling, in preparing its license application. In setting those FEPs, the proposed rule exceeds EPA's statutory authority and is arbitrary and capricious in several ways. First, specific FEPs, as well as EPA's attempts to define and develop them, are in key respects fundamentally inconsistent with the NAS report's findings and recommendations. Second, in setting some of the FEPs, EPA's proposed rule exceeds the bounds of EPA's rulemaking function. Third, EPA's rationales for certain FEPs are arbitrary and capricious, flouting basic mathematics and containing unexplained categorical exclusions. Finally, even if EPA's specific uses of FEPs could otherwise survive scrutiny, they vitiate EPA's rationale for setting a higher numerical standard for evaluating post-10,000 year compliance.

A. The Importance of FEPs

To assess the future performance of its proposed repository, DOE will choose a set of scenarios to model. That set will not include all imaginable variations; instead, DOE will choose a subset of actual scientific possibilities, limited by a specification that certain features, events and processes with a probability of less than 10^{-8}/yr may be screened out as presumptive non-contributors to a probability-weighted dose calculation. These "features, events, and processes" are referred to as "FEPs."

FEP selection obviously has important implications, for it determines which possible scenarios the modelers will and will not consider. While excluding adverse scenarios simplifies the modelers' task, it also decreases the realism of the modeling process. If the scenarios excluded are generally adverse, their exclusion also will skew the modeling toward excessive optimism, making the repository more likely to pass the standard based on an artificial overestimation of its safety.

B. <u>EPA's Approach to FEPs in the Proposed Rule</u>

In its proposed rule, EPA has taken an active role in defining the FEPs that DOE must model. EPA proposes that DOE exclude numerous adverse scenarios from the modeling process, sometimes without specifying what those scenarios are or delineating the standard being used to exclude them. An entirely sensible initial EPA proposal that NRC would have authority to add additional FEPs for the 10,000-year period was unaccountably deleted (apparently at DOE's insistence), and replaced by a series of artificial and unfounded limitations that can have no purpose other than to make it easier for DOE to comply.

First, EPA proposes that DOE should evaluate only those FEPs that have a greater-than 1-in-10,000 chance of occurring over the next 10,000 years. EPA used this screening threshold when it set its original 10,000-year-only standard, and is proposing to retain it despite the now-increased compliance period.

Second, EPA proposes that FEPs not likely to have "significant" effects may be excluded even if those FEPs' probability of occurrence is greater than the numerical threshold described above. EPA has not defined, however, what level of effect would not be considered significant.

Third, EPA has delineated FEPs that DOE should model when considering engineered barrier failures and several natural phenomena. Specifically, EPA's rule would require consideration of a certain subset (and only that subset) of igneous and seismic risks, would require DOE to model constant climate conditions beyond 10,000 years, rather than a range of conditions, and would require DOE to exclude from consideration many potential engineering problems. EPA has stated that numerous other FEPs need not be considered, often without specifying what it is excluding.

As its underlying rationale for its FEP-setting process, EPA relies on the perceived need to manage uncertainty, to make realistic assumptions, and to rule out "extremely speculative" or "fantastical" events. 70 Fed. Reg. at 49048. EPA also bases its rationale on the "systematic conservatism" that it alleges would otherwise infect the modeling process and produce inconsistencies with EPA's own "reasonable expectation" concept. *Id.* Throughout the rule, EPA suggests that this approach is consistent with the NAS's recommendations.

C. <u>Inconsistency with NAS's Recommendations</u>

In several ways, EPA's FEP-setting process violates EnPA's mandate, and the core holding of the Court, for EPA's FEPs and the rationales EPA has employed to support them are inconsistent with NAS findings and recommendations.

1. Reliance on Rationales Rejected by NAS

EPA repeatedly cites a perceived need to avoid uncertainties and over-conservatism as a reason for limiting the FEP-setting process. EPA posits that including all possible scenarios, even if highly unlikely, would prejudice the analysis towards excessive pessimism. Indeed, EPA even claims that its decision to include only scenarios that have at least a 1-in-10,000 chance of occurring over the 10,000 period, *and* that are likely to have "significant effects" (a term EPA never defines) is "extremely conservative." 70 Fed. Reg. at 49049.

But NAS's conclusions were to the contrary. Describing the basic approach involved in performing a probabilistic risk analysis, NAS wrote:

> [t]]o judge compliance against a risk-based standard of the type proposed, a risk analysis including treatment of **all** scenarios that might lead to releases from the repository and to radiation exposures is, in principle, required. To include them in a standard risk analysis, **all these scenarios** need to be quantified with respect to the probabilities of *scenario occurrence and* the probability of their *consequences* to humans, such as health effects of radiation doses.

NAS Report at 72 (italics in original; bold text added). In other words, NAS recommended including a broad range of scenarios and accounting for the remoteness of the more unlikely scenarios by multiplying a scenario's impacts by its low probability of occurrence. Nothing in this passage, or anywhere else in the NAS report, suggests that such an approach would be excessively conservative.

A simplified mathematical example indicates why the NAS was correct that an inclusive analysis is, "in principle," appropriate rather than over-conservative, and why EPA's FEP approach is inherently *unrealistic* and *optimistic*.

> Suppose that events A, B, C, D, and E have probabilities of occurrence of 1%, 3%, 7%, 10%, and 12%, respectively, over the next year.[11] Next, suppose that each event has a likelihood of producing 10 units of exposure if it occurs.

[11] This example assumes that events A, B, C, D, and E are independent, so that the occurrence or non-occurrence of one event does not affect the likelihood of any of the others, or the extent of their effects. A similar assumption is appropriate for many scenarios that may affect Yucca Mountain. For example, nothing about seismic activity is likely to affect the occurrence of climate change, and vice versa. Even where specific variables are weakly or even strongly interrelated, the same general principle holds, though the mathematics becomes more complex: any exclusion of an adverse scenario skews the analysis toward optimism.

> The probable degree of exposures per year thus would be ((probability of A)(exposures per occurrence of A) + (probability of B)(exposures per occurrence of B)…. + (probability of E)(exposures per occurrence of E). Plugging the overall numbers into the equation produces an expectation of 3.3 units of exposure per year.
>
> There is nothing inherently conservative about this prediction; the inclusion of "unlikely" events A and B is compensated by discounting their effect by their likelihood of occurrence. The inclusion of unlikely scenarios thus does not bias the analysis because the unlikelihood of those scenarios is accounted for mathematically.
>
> Now suppose, however, that the regulator has attempted to simplify the modeling by excluding from consideration all events with a less-than-5% chance of occurring. The modeler would then not consider events A and B at all—even though they do have a real-world possibility of occurrence—and would produce a prediction of 2.9 units of exposure per year.[12] Although the change is not huge, defining FEPs to exclude certain scenarios has skewed the prediction toward excessive optimism. And the skewing will increase if, as EPA proposes, probable events with slight effects—for example, an event F which has a probability of 40% but a likely impact of only one unit of exposure—also are excluded.[13]

This example illustrates the fallacy of EPA's assertion that its prescribed FEP approach corrects supposed over-conservatism. In fact, unless compensating mechanisms are introduced, every exclusion of scenarios decreases the *realism* of the calculation, and skews the result toward optimism. The NAS report provides no support

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[12] The problem can be stated somewhat differently. In mathematical terms, excluding an event from consideration is the equivalent of rounding its probability off to 0%—which is the same as assuming it certainly will *not* happen. Of course, any calculation in which all the numbers are rounded off in the same direction will necessarily produce a skewed outcome.

[13] In addition, the modelers will start from a skewed beginning point. Even before the modelers begin purposefully excluding "unlikely" scenarios, they inevitably will have excluded other scenarios simply by failing to think of them. Neither EPA nor the modelers can realistically expect to think of all the things that could go wrong in the next several hundred thousand years—it is axiomatic that engineering and natural systems sometimes behave in unanticipated ways—and some of those oversights could prove highly significant. Yet by not thinking of those scenarios, the modelers will have done the mathematical equivalent of assuming that their probability of occurrence is 0%, and the modeling therefore will be skewed toward optimism even before the process of excluding FEPs begins.

for such skewing, and instead endorses a methodology that provides more realism than that selected by EPA.

2. Excessive Exclusion of FEPs

The NAS report recommends that, in principle, "all" scenarios should be addressed that "might lead to releases from the repository and radiation exposure." NAS Report at 72. Nevada understands that direction not to prescribe an infinite number of runs, but to ensure that EPA's methodology fully accounts for potential releases from the repository and radiation exposure. This NAS recommendation reflects EnPA's underlying statutory mandate for EPA to develop standards for the protection of the public health and safety. As noted below, key exclusions proposed by EPA appear to be inconsistent with the NAS-recommended approach.

EPA has excluded a series of events—many of them entirely unspecified—on the mostly unexplained rationale that their effects would be "insignificant." For example, EPA suggests that if criticality events are not addressed during the first 10,000 years (which DOE had proposed it would not do because it assumes that such failure is unlikely), they also need not be addressed in the post-10,000 year period because, oddly enough, criticality events at such later times would likely have lesser effects than the earlier criticality events EPA already has excused DOE from analyzing. 70 Fed. Reg. at 49051 (stating, without explanation, that "we do not believe such scenarios are either very likely or very important to performance"). As a consequence, EPA's proposed rule would completely excuse DOE from analyzing one of the most worrisome threats posed by the repository, at the very time when waste packages will begin to fail, emptying their fissile contents into pools and piles of unknown (but perhaps critical) geometries. EPA has also excluded engineering failures, such as localized corrosion, on the theory that their post-10,000 year effects would be insignificant. *Id*. Similarly, EPA apparently acquiesces in DOE's assumption that no manufacturing defects will exist, without ever considering whether this assumption is reasonable, let alone sufficiently certain to totally exclude such scenarios from analysis. Indeed, EPA never defines what its standard of significance is, or itemizes all of the FEPs that are being excluded, with the consequence that the rule never explains what events are being left out or how important they might actually be.

On similar grounds, EPA has excluded from consideration several other FEPs on the rationale that their effects will be, in EPA's words, "overwhelmed" by the influence of more important variables. 70 Fed. Reg. at 49053; *see id.* at 49054. Again, EPA is inconsistent at best in defining what FEPs are being excluded on these grounds; while some, like seismic effects on hydrology, are specified, others are left unnamed.[14]

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[14] EPA's general approach is to specify a few engineering, igneous, seismic, or climatic scenarios as the only scenarios that require analysis, expressly or impliedly excluding numerous other scenarios without actually naming them. This methodology creates ambiguity about whether DOE will be responsible for the inclusion or exclusion of those specific FEPs or whether they are excluded by virtue of EPA's rule. It also creates,

Moreover, EPA never addresses the possibility that the comparatively minor FEPs' effects would occur *in addition* to those ostensibly more important ones represented in the scenarios that will be considered, and thus does not consider that this exclusion may well understate direct and cumulative effects. This approach is as irrational as a business declining to account for its smaller expenses on the rationale that they are "overwhelmed" by the larger ones. In reality, all of the expenses, large and small, influence the bottom line, and a failure to account for the small ones leaves any budget projection overly optimistic.

Finally, with only a few exceptions, EPA excludes from consideration FEPs that might be increasingly significant with the passage of time. Some FEPs, like general corrosion, may be of lesser importance during the first 10,000 years if DOE's sanguine predictions are realized, but could become increasingly important in the post-10,000 year period. EPA acknowledges this risk with general corrosion, and requires it to be addressed, but dismisses all other such time-sensitive effects (without even beginning to specify what they are) on the conclusory rationale that "the relevant FEPs are already captured within the 10,000 year screening process, and that any others would be overshadowed by other aspects of the longer-term modeling." 70 Fed. Reg. at 49055.

As a consequence, EPA's rule proposes considering only the limited subset of FEPs that EPA believes, for largely unspecified reasons, to be worth modeling. Even if EPA were correct, and the FEPs DOE will consider turn out to be the most important ones, the collective impact of all the excluded FEPs could have a significant impact on the performance assessment. By categorically excluding those effects from consideration, EPA has departed from the NAS recommendation and introduced a potentially significant level of over-optimism into the assessment.

Those exclusions also exceed EPA's expertise. It would be one thing if EPA's cavalier exclusion of potentially key technical issues were in an area for which the agency has known and Congressionally delegated expertise, such as the health effects of radiation. It is another altogether when the issues concern metallurgy, nuclear physics, seismicity, and climatology.

3. Specific FEP Designations

In addition to inconsistencies between the NAS report and EPA's general approach to using and justifying FEPs, there are also stark inconsistencies between specific FEPs and the findings and recommendations in the NAS report.

a. Seismic FEPs

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perhaps intentionally, the possibility that EPA will claim it has left the decision to DOE, and that DOE will later claim that its exclusions were determined by EPA's rule.

EPA proposes that only seismic effects on the engineered barriers should be considered. While conceding that seismic events also could affect the natural system—particularly by affecting fluid transport pathways—EPA is "proposing that DOE's analysis for seismic events may exclude the effects of seismicity on the hydrology of the Yucca Mountain disposal site." 70 Fed. Reg. at 49056.[15] EPA based this exclusion on two rationales: first, that predicting alterations in flow would be "highly speculative," and second, that any effects of seismic events would be overshadowed by the effects of climate change. *Id*.

These rationales are wholly inconsistent with the NAS's determinations. Rather than suggesting that seismic effects on hydrology could be excluded from analysis, NAS wrote that "[w]ith respect to the effects of seismicity on the hydrologic regime, the possibility of adverse effects due to displacements along existing fractures *cannot be overlooked*." NAS Report at 93 (emphasis added). NAS did also state, as EPA selectively notes, that favorable alterations in the hydrologic regime were possible, but then went on to conclude that "the consequences of these events are boundable for the purpose of assessing repository performance." *Id.* But NAS never qualified its admonition that seismic effects on hydrology "cannot be overlooked" by suggesting, as EPA does now, that climate change might have similar but larger effects. That rationale is patently flawed, for it overlooks the realistic possibility that adverse hydrologic effects arising from seismic events would compound the adverse effects of climate change; there is no reason to assume that adverse climate change effects would preclude adverse seismic effects from occurring.

b. Climate

EPA does know that wetter periods will occur at some future time, and we can analyze how the repository will perform when those periods do occur. EPA suggests that because the site geology will have a dampening effect on climate changes, masking the effects of changes several hundred years or less in duration, changes of longer-lasting duration also need not be analyzed. This also is inapposite. As indicated by the NAS language that EPA cited, this dampening effect should transfer the focus to longer-term climate changes (for example, glacial states that might last for thousands rather than hundreds of years). NAS Report at 93. The short-term dampening effect provides no reason for ignoring long-term changes.

As the NAS report and EPA's own past statements indicate, significantly wetter climates will occur and will adversely impact repository performance. In mandating that those conditions be assumed out of existence, EPA's proposed rule would ignore the NAS's clear recommendation.

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[15] At 70 Fed. Reg. 49056, EPA gives DOE a blanket license to exclude from consideration any seismic effects other than the "key aspects of seismicity discussed above." EPA never specifies which effects it is excluding from consideration, or why "they can reasonably be excluded from analysis over the period of geologic stability," so this blanket exclusion lacks any reasoned basis.

Moreover, as the report of Dr. Thorne indicates (Appendix E), EPA's specification that only constant climate conditions may be considered ignores the possibility that other factors influenced by global warming will have a substantial effect on deep percolation of water into the repository.

c. Volcanism and Igneous Events

EPA states that DOE need only consider as FEPs volcanic events that have occurred, or may reasonably be inferred to have occurred, during the Quaternary Period, which includes approximately the last 1.6 million years. 70 Fed. Reg. at 49052. The rationale, apparently, is that if events haven't occurred during the last 1.6 million years, the probability of their occurrence within the next million years is negligible.

For events likely to occur on a shorter time cycle (e.g. climate shifts), this might be a reasonable assumption, since a 1.6 million-year period is long enough to encompass numerous climate cycles and provide a sense of the full range of possibilities. Volcanic eruptions in the Yucca Mountain area, however, occur infrequently and irregularly, and the activity in one 1.6-million year period—a long period by human standards, but a short one for many geologic processes—may not be an accurate preview of future activity. To assume that the volcanic events of the next million years are bounded by the events of the previous 1.6 million years is somewhat like assuming that Chicago's weather tomorrow can be predicted, with certainty, by reviewing the weather reports from the previous two days.

Indeed, EPA's own consultant's report concedes that during the Pliocene Epoch (5.2 million years before present to 1.6 million years before present), several larger-scale eruptions occurred at the site. Cohen Report at 10-1 to 10-2. Moreover, EPA's own rule acknowledges that the type of eruptions that formed the tuffs at Yucca Mountain is not the same as the type of eruptions that are known to have occurred more recently. EPA at 70 Fed. Reg. at 49058. The difference is important; in comparison to most basaltic eruptions, the eruptions that produce welded tuffs generally are gigantic.

Thus, in requiring that DOE model only events that occurred during the Quaternary period, EPA is excluding possible volcanic events from analysis. Moreover, it isn't excluding just any events, but instead is selectively leaving out larger events. While such events have low probabilities, since volcanic events in the region are infrequent, their effects, if they do occur, could be major, and there is no foundation for EPA's rationale for screening them out entirely.

D. <u>EPA's FEP-Setting Exceeds EPA's Authority and Expertise</u>

In setting FEPs for certain physical parameters of the Yucca Mountain analysis, EPA proposes to use the rulemaking process to pre-determine adjudicative facts, and to do so in areas well outside its expertise. In so doing, EPA would exceed the limited authority Congress conferred upon it, both by exceeding its rulemaking function and by undertaking tasks that Congress delegated elsewhere.

In the NWPA and EnPA, Congress specified a clear division of authority—one which built upon EPA's traditional role (incorporated in section 121 of the NWPA and the 1970 Reorganization Plan that established EPA). EPA's one and only duty is to promulgate, by rulemaking, a health-based standard "based upon and consistent with the NAS's findings and recommendations." EnPA § 801. DOE, not EPA, is to select a site and write an application for a license. The NRC, not EPA, is to judge, through an adjudicatory proceeding, whether that license application satisfies EPA's health-based standard, and whether the license should be granted. Like any administrative agency, EPA has no power beyond that delegated to it by law, and may not assume the functions delegated to its sister agencies.

The significance of Congress's division of authority is underscored by its concordance with the fundamental separation of powers that underlies our entire system of governance. Our Constitution itself has as its core principle the separation of powers between legislative, executive, and judicial entities; it does not contemplate the same entity simultaneously functioning as advocate, rulemaker, and judge. Likewise, "the entire (Administrative Procedure) Act is based upon a dichotomy between rule making and adjudication." ATTORNEY GENERAL'S MANUAL ON THE ADMINISTRATIVE PROCEDURE ACT (1947). In dividing authority among EPA, DOE, and the NRC, Congress utilized those core separation-of-powers principles, granting EPA only a limited rulemaking role, and EPA has no power to blur those distinctions. Indeed, the gravity of the Yucca Mountain decisions accentuates the importance of Congress's mandate; if government agencies are to decide that part of Nevada will be contaminated for a million years, that decision ought at the very least to be made through a process of checks and balances, and the agencies involved must respect the limits Congress placed upon their roles. EPA therefore is required, in promulgating this standard, to limit itself to the narrow and constrained rulemaking task Congress delegated to it.

Yet many of the specific FEP determinations EPA's proposed rule would make are not properly within the scope of EPA's rulemaking task, and are certainly far outside its traditional expertise. The grant of rulemaking authority in the EnPA is based on the prior grant of rulemaking authority in the NWPA. Both statutes are based on the original grant of radiation standard setting authority in Reorganization Plan No. 3 of 1970. That grant (and therefore the grant in the EnPA) is expressly limited to the setting of standards defined as "limits on radiation exposures or levels, or concentrations or quantities of radioactive material" in the environment. The rest was reserved exclusively to NRC as the agency responsible for implementing the EPA standards through the licensing process.

Here, EPA has used rulemaking to pre-set the highly technical assumptions that DOE's modelers will make, and to pre-judge the resolution of site-specific licensing issues that are the exclusive province of NRC. Such things as specification of FEPs do not remotely qualify as the setting of limits on exposures, levels, or concentrations of radiation. Indeed, in the past, NRC has vigorously opposed EPA intrusions into its repository licensing functions very much like the ones EPA now proposes. *See* NRC letters to EPA and NRC memoranda found on NRC's Licensing Support Network at NRC 000024406 and NRC 000024461.

Scientific determinations such as this are more properly made in the NRC licensing review where there is the flexibility to account for more recent scientific advances and to adjust to specifics of the performance assessment actually proposed as the basis for licensing. EPA itself has no power, in its rulemaking process, to review DOE's current draft applications and preliminary modeling work and utilize that work to screen certain scenarios out of the site evaluation process. By constraining the modeling assumptions, EPA has gone far beyond its limited rule-writing role and instead has injected itself into NRC's licensing function.

EPA's own past statements acknowledge that these determinations are not EPA's to make. In promulgating 40 C.F.R. Part 197's standard, EPA did not purport to specify FEPs that DOE would or would not model. Instead, EPA noted that "[t]hese considerations and decisions properly belong to the implementing authority." 66 Fed. Reg. 32074, 32126 (July 13, 2001). EPA specifically explained that in the WIPP process, "where [EPA] had both the standard-setting and implementing authority," it had specified "requirements for modeling techniques and assumptions." *Id.* But it concluded that in the Yucca Mountain rulemaking, where such implementing authority did not repose in EPA, such "requirements go well beyond the simple statement of a compliance measure," and, with the exception of the FEP discussed below, it did not establish them. *Id.* Likewise, EPA specifically noted that it declined "to specify that DOE must use a particular modeling approach to demonstrate compliance with the standards," and instead stated that "DOE (the organization responsible for developing the license application) and NRC (the authority responsible for the approval of the disposal facility) should make these decisions." *Id*. at 32127 (parentheses in original).

E. EPA's FEPs Vitiate EPA's Rationale for a Higher Standard and for Use of the Median

EPA's FEPs also undermine the key rationales for EPA's creation of a higher numeric standard in the post-10,000 year period, and for EPA's position shift to require use of the median, rather than the mean, for projecting compliance.

EPA proposes to justify both its 350 millirem/year standard and its use of the median primarily on the rationale that both are necessary to manage long-term uncertainties in performance assessment. EPA's theory appears to be that a combination of uncertainty and compounding conservative assumptions will unavoidably skew DOE's modeling, and that, rather than expecting DOE to fix those perceived modeling problems, EPA must for some reason compensate for that skewing by using a commensurately skewed higher standard and a less conservative statistical compliance measure.[16]

[16] Nevada has addressed the many other problems with this theory elsewhere herein.

The use of predetermined FEPs undercuts EPA's uncertainty rationale. By specifically defining future states for crucial FEPs, such future climate states, EPA manages uncertainty out of the modeling process. Having taken that step, it is inconsistent to *optimistically* adjust the end-goal to account for negative uncertainties that the modelers have been required to remove. Essentially, this methodology double-counts the perceived uncertainty.

The use of FEPs also thoroughly undercuts EPA's predetermination that DOE's modeling process will be overly conservative. As shown in the mathematical example above, arbitrary exclusion of FEPs can inherently skew the modeling process toward optimistic outcomes.

XIX. EPA Impermissibly Legislates Other Adjudicative Facts

The proposed EPA rule includes various "findings" of adjudicatory fact—that is, findings of fact that are applicable only to Yucca Mountain and that should be the subject of NRC review of the DOE license application in the NRC licensing hearing. Those "findings" also are made without any significant factual inquiry on controversial and critical subjects over which EPA has no particular expertise.

For example, EPA's entire "over-conservatism" and "uncertainty" theories rest on pre-determination of adjudicative facts. As Dr. Thorne points out in Appendix C, variations in uncertainty and conservatism with time are matters to be derived by detailed assessment modeling, which can only be done in consideration of an actual license application, and cannot be determined *a priori* by rule, as EPA presumes in its rule. EPA does not, and cannot, rely on universally applicable legislative facts to support this theory, for DOE's models will be[17] specific to Yucca Mountain. Likewise, the source EPA cites for its over-conservatism rationale is specific to DOE's Yucca-Mountain models. *See* 70 Fed. Reg. at 49021 (citing Cohen, Assumptions, Conservatisms, and Uncertainties in Yucca Mountain Performance Assessments (2005)). Accordingly, the inquiry about whether DOE's modeling efforts will be improperly conservative, improperly optimistic, or somewhere in between is a classic determination of adjudicative fact, and EPA has no power to extract that determination from the NRC's adjudicative process, prejudge its outcome, and use that prejudgment as a basis for its rule.

EPA's proposed rule not only would involve *ultra vires* resolutions of adjudicative facts; it would resolve those facts before they are ripe for adjudication. The EPA findings

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[17] EPA's attempt to alter its standard to accommodate the anticipated insufficiencies in DOE's modeling is thus suspect for the additional reason that EPA does not know whether those perceived insufficiencies actually will exist, and EPA has effectively altered its rule to accommodate perceived flaws in what is a partial draft License Application, since a complete *draft* is unavailable.

are based on what is, in effect, an incomplete collection of information, some of which may be relied upon by DOE in its eventual license application, and some of which may not be. Because DOE has not yet submitted an application (and has in fact taken every conceivable measure to hide it from public view), all of its modeling is preliminary and subject to change. The final application will undoubtedly include numerous important changes from the information relied on in this rule, and when DOE actually submits an application the perceived flaws that led EPA to adopt particular positions on various FEPs and skew its standards may no longer exist. Moreover, none of that preliminary modeling has been the subject of a full review and concurrence by DOE, NRC or EPA, and the iteration relied upon by EPA already has apparently been superseded by another draft. EPA's adjudicatory decisions thus are premature as well as *ultra vires*.

Each of these legal defects has the unlawful effect of depriving Nevada and other interested persons of their rights to an adjudicatory hearing on contested issues of adjudicatory fact under the Atomic Energy Act and NRC's Rules of Practice.

To be sure, to a limited extent a Yucca specific rule must be based on findings of adjudicative fact, for example, a finding that the Yucca site is such that reasonable projections of peak dose can be made. But clearly Congress limited such adjudicative fact-finding to those facts essential for the promulgation of health-based standards, properly defined as limits on radiation exposures, levels or concentrations in the environment. Moreover, the adjudicative findings necessary for standard-setting were to be made by NAS. EPA's findings of fact are well in excess of those necessary to accomplish this limited rulemaking function and go well beyond, and in some respects are inconsistent with, the findings of NAS. Indeed, as pointed out above, EPA's rule is in danger of complete collapse when the proposed findings of fact in the DOE license and the NRC findings of adjudicatory fact in the licensing process turn out to be inconsistent with the very premises for the EPA rule. Such a collapse would be avoided if EPA limited its rule, and its underlying findings, to policy judgments about acceptable levels of risk based on NAS findings of fact about Yucca.

XX. EPA's Rule Impermissibly Prejudges NRC Licensing

A. "Implementability" and Prejudgment

EPA's heavy reliance on the concept of "implementability" is the first indication of EPA's prejudgment, for EPA has defined its "implementability" goal in such a way that it assumes a license must be granted. EPA's proposed rule suggests that a standard must be "implementable," ostensibly meaning that it must provide a measure capable of distinguishing a good repository license application from a bad one. *E.g.* 70 Fed. Reg. at 49029. This definition is reasonable enough; a standard against which compliance could not be measured might as well be no standard at all. Yet the manner in which EPA applies this concept reveals, for numerous reasons, that EPA misconstrues it by deciding that any standard that might cause Yucca to fail is not implementable.

First, EPA impliedly defines an "implementable" standard as a standard that some repository somewhere could pass. Without offering any basis for this conclusion—and without acknowledging that it is directly contrary to the conclusions of the NAS, which determined that a traditional apportioned standard could be used through the time of peak dose—EPA then suggests that because of inherent "uncertainties," no repository anywhere could pass a traditional, 15 millirem/year standard, and that such a standard therefore is not implementable for longer-term compliance assessment.

Moreover, EPA has no basis for assuming that a "safe" repository could not pass a traditional 15 millirem/year standard, and that such a standard therefore is not implementable. The NAS came to no such conclusion, and instead determined that current site characterization capacities are sufficient to project compliance with a traditionally apportioned standard through the time of peak dose. Moreover, EPA's rule does not consider experience at other actual repository sites, and EPA therefore lacks any basis for asserting that no site could pass a 15 millirem standard. Another location with true geologic isolation—a site without permeable, fractured rock that allows groundwater to flow through the repository—might well pass the traditional 15 millirem standard even at peak dose. Indeed, as discussed below, DOE's WIPP repository -- the only operating repository in the world -- is just such a location. Having considered only Yucca Mountain in assessing whether 15 millirem/year is "implementable," EPA has no basis to suggest that the standard is universally impossible to meet.

Because EPA's "implementability"-based rejection of a traditional standard is based solely on its review of Yucca Mountain, that rejection is in reality a prejudgment that the only "implementable," and thus acceptable, standard is one that Yucca Mountain could meet. Implementability thus is only an excuse for setting a standard that allows Yucca Mountain to be licensed, regardless of its safety, and EPA's use of that concept betrays its procrustean attempt to predetermine the outcome of the licensing process.

B. <u>Uncertainty and Prejudgment</u>

EPA's treatment of supposed "uncertainty" further evinces prejudgment. Under EPA's reasoning, uncertainty and implementability are closely connected; because of compounding uncertainties, EPA believes, a low standard is not implementable for long-term compliance assessment, and a higher standard must be used. This reasoning amounts to a predetermination that Yucca Mountain should be licensed.

First, EPA's relaxation of standards betrays a prejudgment that the repository should be licensed even if DOE and NRC cannot determine whether it will work. Even if uncertainties do make predicting compliance with a traditional standard difficult regardless of site-specific characteristics,[18] that does not mean that the standard is not

[18] The NAS, of course, specifically rejected this position, finding that meaningful long-term compliance projections could be made and that those projections could be measured against a traditional, apportioned standard.

implementable, for there is nothing unimplementable or unreasonable about a standard that requires the applicant to bear the burden of addressing uncertainty. Just as the FDA does not license drugs until it has some certainty about how they will perform, and does not consider rules requiring such demonstrations "unimplementable," EPA cannot alter its standards to facilitate the licensing of a repository with uncertain prospects of success. Indeed, that uncertainty may reflect flaws in the siting or design of the repository, or may simply reflect the fact that DOE's modeling and site characterization capabilities are not sufficiently advanced for it to demonstrate whether or not a repository will perform adequately. Under such circumstances, uncertainty provides a reason *not* to license repositories, not an excuse to consider traditional health-based standards unimplementable. Relaxing standards to accommodate uncertainties indicates an unlawful predetermination that repositories should be licensed.

Second, because the key uncertainties EPA cites as affecting DOE's long-term performance assessment are *specific to Yucca Mountain*, EPA's implementability/uncertainty rationale betrays EPA's attempt to predetermine licensing by tailoring the standard to accommodate the known *weaknesses* of the Yucca Mountain site.

Uncertainty exists at Yucca Mountain primarily because water naturally percolates through the repository due to fractured geology. For two primary reasons, that water flow makes engineering uncertainties crucially important. First, it promotes corrosion, which EPA has observed is "exactly the critical element in estimating the timing and magnitude of peak dose." 70 Fed. Reg. at 49026. Second, because it negates the existence of geologic containment, it places increased importance on the engineered barrier system, and while it is undisputed that those barrier systems will eventually fail, no one is certain when that failure will occur. Additionally, because water flow rates may vary, water infiltration creates some uncertainty about the rate at which radionuclides will move through the subsurface environment.

These uncertainties are not inherent in all potential repository sites. Instead, they are peculiar to the permeability and fractures of Yucca Mountain's rock.[19] At a site providing true geologic barriers—such as the WIPP site, where the geology provides total containment—neither source of uncertainty would exist. Water would not enter or leave the system, and inevitable failures of the engineered barriers would be compensated for by the impermeability of the surrounding geologic formation.

EPA's reliance on uncertainty as the basis for its lax standard therefore constitutes EPA's determination that the standard should be tailored to accommodate the flaws in the Yucca Mountain site. That rationalization and the resulting lax standard completely undermine the integrity of EPA's rulemaking by basing the standard on non-health-related factors that EPA has no power to consider. Additionally, that rationalization usurps the NRC's jurisdiction to determine whether or not the license should be issued by

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[19] The importance of these two sources of uncertainty is vastly greater than that of most others. Additionally, many other uncertainty sources—the threat of volcanic or seismic activity, for example—also are site-specific.

crafting a standard to *ensure* that a license will issue. A standard designed to *measure* whether a repository protects public health cannot be tailored to the weaknesses of that very repository without tainting the entire licensing process with prejudgment.

XXI. EPA Improperly Delegates Its Own Rulemaking Role

In addition to usurping roles Congress delegated to other agencies, EPA's proposed rule would unlawfully delegate away EPA's own core responsibility for setting a standard. Rather than following Congress's and the court's direction to set a standard applicable to peak dose, EPA proposes to set little more than a guideline, and to allow the NRC to consider a modeled projection of compliance with that guideline as little more than a "factor" in its ultimate compliance determination. By declining to promulgate a true standard, EPA impermissibly would delegate its discrete and limited rulemaking role to the NRC.

The NWPA and EnPA direct EPA to promulgate a binding standard. EnPA section 801(a)(1) states that EPA's "standards shall prescribe the maximum annual effective dose equivalent to individual members of the public from releases" of radioactive material from the repository. *See NEI v. EPA*, 373 F.3d at 1262 (citing EnPA). The phrase "prescribe the maximum" clearly indicates Congress's demand for a binding limit, and does not allow for the possibility of approval of a repository predicted to produce higher doses. Likewise, Congress's use of the word "standard" indicates Congressional intent that the standard be an absolute limit; elsewhere in environmental regulation, where Congress has demanded that EPA "prescribe… standards," those standards are understood to provide limits that may not be exceeded. *See*, *e.g.*, 42 U.S.C. 7409 (providing for air quality standards, with which state air quality plans must demonstrate compliance); 42 U.S.C. § 9621 (requiring hazardous waste site cleanups to meet public health and safety standards). Finally, Congress's requirement that EPA promulgate its standards "by rule" indicates the binding nature of those standards; unlike policy statements or guidance documents, rules that implement Congress's statutory mandates by definition have coercive force. *See Chrysler Corp. v. Brown*, 441 U.S. 281, 302 n.31 (1979) (citing the 1947 Attorney General's manual); *Batterton v. Marshall*, 648 F.2d 694, 701-02 (D.C. Cir. 1980).

Notwithstanding those Congressional directives, EPA proposes, in parts of its new rule, that its standard would not be binding unless the NRC decides to treat it that way, and that the NRC would have discretion to license a site even where the compliance evaluation projects a violation of the standard. EPA does suggest that under its new rule, "the post-10,000 year analyses are now proposed to be part of the 40 CFR part 197 standards with a quantitative limit imposed." 70 Fed. Reg. at 49028.[20] However, EPA

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[20] EPA's rule does also contain several statements suggesting that the standard will be binding. For example, EPA acknowledges that "we believe that the best way to address the Court decision is to establish a numerical compliance standard for the time of peak dose so that a clear test for compliance decision-making can be applied to the results of quantitative performance assessments." 70 Fed. Reg. at 49031. EPA also ostensibly

also proposes to "continue [40 CFR Part 197's] general approach" of leaving "the degree of 'weight' that should be given to these very long-term assessments" as "an implementation decision that should be left to the NRC to determine, by balancing the inherent uncertainties in these projections against the projected dose levels." *Id.*[21] Elsewhere, EPA suggests that compliance projections can "form a key *part* of the basis for a licensing decision," 70 Fed. Reg. at 49029 (emphasis added). It argues that "we do not want to place more regulatory emphasis on peak dose projections than can be justified." 70 Fed. Reg. at 49030. It suggests that "quantitative projections should be considered less for their strict numerical outcomes and more as one component in a qualitative evaluation of the overall safety case." *Id.* And it further states that NRC may consider a dose projection exceeding the dose standard not as a bar to licensing, but rather as only a "particularly important part of the 'full' record." 70 Fed. Reg. at 49034. Finally, in a statement that ignores the NAS's conclusions about the manageability of scientific uncertainty, EPA suggests that NRC's "regulatory judgment must bridge the gap between what science can show and the unprecedented time frames involved." 70 Fed. Reg. at 49030.

It is one thing to promulgate a dose standard and leave the implementation details (the selection of models, FEPs, and the like) to NRC. It is quite another to set a “standard” and give NRC the discretion to grant a license that does not comply with it.

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rejects a dose "target" in favor of a limit, though its description of that limit makes the distinction sound like one without a difference. *Id.* at 49033. And EPA does state that "DOE must satisfy NRC that a specified portion of the distribution satisfies the dose criterion." *Id.* at 49041. Those statements, if not contradicted elsewhere, would provide sufficient assurance that the standard truly will be a standard, but the presence of those other contradictory statements renders EPA's meaning ambiguous.

[21] EPA also states:

> We anticipate that if these very long-range performance projections (beyond 10,000 years) indicate that repository performance would degrade dramatically under a wide range of conditions at some point in time, that this would become a concern in the licensing decision. If such a dramatic deterioration were projected to occur close to the regulatory time period it would be a more pressing concern for licensing decisions than if it were to occur many hundreds of thousands of years in the future.

70 Fed. Reg. at 49028. This statement is problematic for several reasons. First, it indicates that EPA still construes the "compliance period" as 10,000 years in length, notwithstanding the clear recommendation of the NAS and holding of the Court. Second, by stating that significant deterioration after 10,000 years would be just a *concern*, it implies that such deterioration need not prevent licensing, even if it creates a violation of the standard. Those implications are wholly inconsistent with both Congress's requirement that EPA set a maximum dose standard and with the Court of Appeal's mandate that the standard, and thus the "regulatory time period," extend to peak dose.

These statements all suggest that EPA is granting NRC discretion to decide whether EPA's standard really will be a mandatory standard, or whether it will just be a guideline. But Congress did not delegate such decision-making authority to NRC; it tasked EPA with setting, "by rule," a standard, and directed NRC to see that the standard was implemented. EPA may not sub-delegate its standard-setting authority by allowing NRC to choose whether or not it must comply with EPA's rule. EPA must clarify that the standard will be what Congress demanded: a binding limit on the projected peak dose from the repository.

Indeed, EPA's new sub-delegation is particularly suspect because of its close resemblance to elements of the rule the court already set aside. In the original 40 C.F.R. Part 197 standard, EPA required DOE to provide dose projections through peak dose, but allowed NRC discretion to decide how to factor those projections into its licensing. The Court expressly rejected this approach, finding it inconsistent with Congress's mandate that EPA set a standard applicable through peak dose. 373 F.3d at 1273. Yet EPA's new rule, by again suggesting that NRC has discretion to grant a license despite projected exceedances of the dose limit, is functionally identical to the rule the Court already rejected as failing to fulfill EPA's statutory mandate.

Finally, EPA's direction to NRC regarding establishment of climate conditions and infiltration rates is no standard at all, but merely an unlawful intrusion into NRC's licensing process.

XXII. The New Rule Improperly Construes "Reasonable Expectation"

A. EPA's Attempt to Relax "Reasonable Assurance"

In its proposed rule, 70 Fed. Reg. at 49014, EPA purports to rely upon and apply a "Reasonable Expectation" standard in evaluating repository compliance, emphatically urging *NRC* to employ it as well in its *implementation* of dose and time-of-compliance standards and calling Reasonable Expectation not just an optional gauge of safety but "a critical element in implementing our standards." *Id.* at 49020. EPA thus seeks to base its rule on some special notion of "reasonable expectation" that distinguishes it from the traditional standard of reasonable assurance. It is impossible to understand what effect "reasonable expectation" had on EPA's proposal, because EPA does not explain how reasonable expectation is different from reasonable assurance. However, in the context of EPA's present rulemaking, "Reasonable Expectation" cannot mean anything significantly different from the meaning previously ascribed to it in Court by both EPA and NRC, when it was agreed that reasonable expectation and reasonable assurance meant the same thing in repository licensing. EPA cannot proceed as if the agreed judicial resolution of this issue had never happened. In Court, Nevada's challenge to use of a "Reasonable Expectation" standard was rendered moot by those agencies' agreement that it was an equivalent standard to the well-known and commonly construed "Reasonable Assurance" standard of safety that peppers all of NRC case law.

B. Background: Judicial Resolution of a Convoluted Disagreement

On June 21, 1983, NRC promulgated Final Rule 10 C.F.R. Part 60 (48 Fed. Reg. 28194), which explained:

> The Reasonable Assurance standard is derived from the finding the Commission is required to make under the Atomic Energy Act that the licensed activity provide "adequate protection" to the health and safety of the public; the standard has been approved by the Supreme Court. *Power Reactor Development Co. v. Electrical Union*, 367 U.S. 396, 407 (1961). This standard, in addition to being commonly used and accepted in the Commission's licensing activities, allows the flexibility necessary for the Commission to make judgmental distinctions with respect to quantitative data which may have large uncertainties (in the mathematical sense) associated with it.

Id. at 28204.

The Commission explained that the Reasonable Assurance standard does not create a standard that is impossible to meet. On the contrary, it parallels language the Commission has applied in contexts other than that of a nuclear waste repository, such as the licensing of nuclear reactors, for many years.

NRC proposed amendments to its repository licensing rule in 1999. 64 Fed. Reg. 8640 (Feb. 22, 1999). The Commission proposed that the results of a performance assessment be the sole quantitative measure used to demonstrate compliance with post-closure dose limits, providing "a Reasonable Assurance, on the basis of the record before the Commission, that the performance objective will be met is the general standard that is required." *Id*. at 8650. The NRC specifically recognized that in establishing Reasonable Assurance, allowance must be made for the time period involved, the hazards and the uncertainties involved, and assumed that the applicant would use complex predictive models supported by limited data from field and laboratory tests and would necessarily rely on computer modeling to determine whether a proposed repository met performance objectives. *Id*.

When NRC published its Final Rule, 66 Fed. Reg. 55732 (Nov. 2, 2001), it explained in response to public comments its continuing reliance on the Reasonable Assurance standard. Specifically addressing a comment filed by EPA, NRC noted EPA's position that Reasonable Assurance was *not appropriate* for use in the licensing of a repository where projections of performance have inherently large ranges of uncertainty. *Id*. at 55,739. Instead, EPA proposed the application of a looser, "Reasonable Expectation" standard, because it asserted that Reasonable Assurance had come to be associated with a level of confidence that is not appropriate for the very long-term analytical projections that would be necessary for evaluating Yucca Mountain. *Id*. In response, NRC explained: "It is the Commission's responsibility to determine whether DOE has or has not demonstrated compliance. The Commission does not believe that

NRC's use of 'Reasonable Assurance' as a basis for judging compliance compels focus on extreme values for representing the performance of a Yucca Mountain repository. Further, if DOE is authorized to file a License Application, and if the Commission is called on to make a decision, irrespective of the term used, the Commission will consider the full record before it." *Id*. at 55739-40.

Nonetheless, NRC made what it considered to be a semantic concession, and a partial one at that. It agreed to utilize a "Reasonable Expectation" standard for evaluation of Yucca's post-closure performance assessment but to continue to utilize Reasonable Assurance for pre-closure compliance assessment. *Id*. at 55740. At the same time, the Commission made clear its view that the choice of wording was a distinction without a difference, explaining: "The Commission will adopt EPA's preferred standard of 'reasonable expectation' for purposes of judging compliance with the numerical post-closure performance objectives. However, the Commission wants to make clear that its proposed use of 'reasonable assurance' as a basis for judging compliance was not intended to imply a requirement for more stringent analyses (e.g., use of extreme values for important parameters) or for comparison with potentially more stringent statistical criteria." *Id*. at 55740.

In its contemporaneous 2001 issuance of its original Part 197 (66 Fed. Reg. 32074), EPA discussed its Reasonable Expectation standard, conceding: "We believe that Reasonable Expectation provides an appropriate approach to compliance decisions; however, with respect to the level of expectation applicable in the licensing process, NRC may adopt its proposed alternative approach." *Id*. at 32101. At the same time, EPA emphatically backed off on the perception it had created that Reasonable Expectation was somehow intended to be a more lenient standard, observing in response to public comments: "Some comments suggest that our approach would allow the use of less rigorous science for the assessment of disposal system performance and licensing. This perception may have arisen from our choice of wording in the proposal, where we stated that NRC may elect to use a more 'stringent' approach. *Such an interpretation was not our intent*. . . . We therefore must disagree with these comments that Reasonable Expectation requires less rigorous proof than NRC's Reasonable Assurance approach. We do not believe that the Reasonable Expectation approach either encourages or permits the use of less than rigorous science in developing assessments of repository performance for use in regulatory decision making. On the contrary, the Reasonable Expectation approach takes into account the inherent uncertainties involved in projecting disposal system performance." *Id*. at 32102. (Emphasis supplied.)

Significantly, EPA added that Reasonable Expectation "requires that the uncertainties in site characteristics over long time frames and the long-term projections of expected performance of the repository are fully understood before regulatory decisions are made." *Id*. EPA explained that performance scenarios should be developed without omitting important elements simply because they may be difficult to quantify with high accuracy, and said that elicited values for relevant data should not be substituted for actual field and laboratory studies. *Id*. EPA went on to explain that the gathering of credible information that would allow a better understanding of the uncertainties in site characterization data that would bear on the long-term performance of the repository should not be subjugated simply for convenience, insisting: "We do not believe that Reasonable Expectation in any way encourages less than rigorous science and analysis." *Id*. at 32102-3.

EPA denied the suggestion that its use of a Reasonable Expectation approach intrudes inappropriately into the area of *implementation*, which EPA said is the province of NRC. *Id*. at 32103. In this regard, EPA deferred to NRC's judgment: "The implementing agency is responsible for developing and executing the implementation process and, with respect to the level of expectation applicable in the licensing process, is free to adopt an approach it believes is appropriate." *Id*. This concession was made by EPA in the face of "a majority of public comments" stating that it was unnecessary for EPA to include assurance requirements in its rule because that was an implementation matter properly within NRC's jurisdiction. *Id*. EPA concluded: "Therefore, based upon the public comments we received regarding this rule . . . we did not include assurance requirements in this rule." *Id*.

EPA expanded on its discussion of Reasonable Expectation in its "Evaluation of Potential Economic Impacts of 40 C.F.R. 197: Public Health in Environmental Radiation Standards for Yucca Mountain, Nevada" (June 2001). EPA emphasized that Reasonable Expectation would not exclude important parameters from performance assessments because they are difficult to quantify to a high degree of confidence. *Id*. at 5-2. EPA explained that many natural features important to repository performance cannot be extensively characterized, and many exhibit a high degree of inherent variability. *Id*. at 5-5. EPA insists that Reasonable Expectation requires performance assessments for a geologic repository to recognize the inherent uncertainties and limitations of characterizing the natural system. *Id*. at 5-6. EPA acknowledged that "bounding" approaches that exclude important processes that will affect performance are inappropriate because these processes are not readily quantified with high precision and accuracy, and they pose a danger of disguising important aspects of the site performance. *Id*. at 5-11.

After both EPA's and NRC's initial Yucca Mountain regulations were promulgated, NRC promulgated a proposed rule to address *which* FEPs (features, events, and processes) would be required to be included in DOE's performance assessments for the Yucca repository. 67 Fed. Reg. 3628 (Jan. 25, 2002). NRC noted that EPA's standards in general terms did not require the addressing of "unlikely" FEPs, but authorized the proposed rulemaking amendment to 10 C.F.R. Part 63 because "EPA did not define unlikely FEPs in its standards, but rather, *left the specific probability of the unlikely FEPs for NRC to define*." *Id*. at 3628. (Emphasis supplied.) NRC explained its rationale for dealing with the FEP issue well before the licensing proceeding:

> Although the Commission could review and approve a probability limit in the context of its review of a potential DOE License Application, it is proposing to set this limit in advance, through the rulemaking process, so that it will have the advantage of public views on this question, and so that

> DOE, interested participants, and the public will have knowledge, before the License Application, of what probability the Commission would find acceptable.

Id. at 3629.

The NRC specified "unlikely" and "very unlikely" probabilities of occurrence and provided that very unlikely FEPs need not be considered by DOE, but that "unlikely" FEPs must be considered in the performance assessment for the individual protection standard. *Id*. at 3630.

Any remaining concern that Reasonable Expectation might be a more lenient standard than Reasonable Assurance (which had been stoutly denied by EPA), and any concern that NRC's adoption of Reasonable Expectation for the assessment of post-closure compliance assessment at Yucca Mountain was an unlawful departure from its longstanding (and Supreme Court approved) Reasonable Assurance standard, were put to rest in the oral argument and final decision of the *NEI* case. In that case, Nevada argued that: "[T]hat in other contexts, NRC requires reasonable assurance that the licensed activity adequately protects the public health and safety and that, in jettisoning the time-tested and Supreme Court-approved standard (citation omitted), in favor of a 'vague' 'reasonable expectation' standard, NRC 'overt[ly]' violated the AEA and the NWPA and otherwise acted arbitrarily and capriciously." 373 F.3d at 1300.

The Court, however, concluded that it would not address the matter because, in the presence of EPA counsel, NRC had admitted in oral argument that there was "no consequential difference" between the Reasonable Assurance and Reasonable Expectation standards and that the two are in fact "virtually indistinguishable." *Id.* The court went on to note that, during oral argument, NRC counsel confirmed that the two standards are "substantively identical." *Id.* The court noted Nevada's satisfaction with NRC's concession that Reasonable Assurance and Reasonable Expectation are identical standards. *Id.*

C. <u>EPA's Reversion to a More Lenient Standard</u>

EPA's current proposed rule is a radical departure from the advertised bases of both the Reasonable Expectation and the Reasonable Assurance concepts, in that EPA's proposal (1) fails to focus performance assessments and analyses on the *full range of defensible and reasonable parameter distributions*; and (2) seeks to invade the jurisdiction of NRC as the implementing authority for licensing of the proposed Yucca repository.

In its analysis of DOE's Yucca Mountain performance assessments, predating the EPA proposed rule, Cohen & Associates noted that:

- "Inappropriate simplifications can mask the effects of processes that will, in reality, determine disposal system performance, if the uncertainties involved with these simplifications are not recognized." OAR-2005-0083-0085, at 12-2.

- "If the uncertainties in site characterization information and the modeling of relevant features, events, and processes are not fully understood, results of bounding analyses may not be bounding at all." *Id*.

- "The Reasonable Expectation approach is aimed simply at focusing attention on understanding the uncertainties in projecting disposal system performance so that regulatory decision making will be done with a full understanding of the uncertainties involved." *Id*.

In sum, to the extent EPA's discussion, reasoning, and application of a new "Reasonable Expectation" standard can even be understood, it appears vaguely to apply a set of criteria that together amount to far less than the simple and well-understood concepts of either Reasonable Assurance or Reasonable Expectation.

XXIII. The New Rule Draws a False Comparison to WIPP

EPA's attempt to analogize the Yucca situation to that of DOE's repository site for the Waste Isolation Pilot Plant ("WIPP") in Carlsbad, New Mexico, is grossly misplaced. EPA certified the WIPP site under 42 C.F.R. Part 191. The compliance standard for that site was a wholly appropriate 15 millirem/year, and the compliance period was 10,000 years. EPA attempts to suggest that the Yucca situation is "unprecedented" relative to WIPP because at Yucca, EPA is now required by the Court to evaluate performance out to a time period of one million years. For several reasons, this suggestion is a distortion of the facts and could not be more wrong.

First, the WIPP repository is a site for medium-level transuranic radioactive waste, while the Yucca repository must handle the much more radioactive high-level radioactive waste and spent nuclear fuel.

Second, the WIPP repository is sited not in fractured volcanic tuff but in a large, stable, and fully isolating salt deposit. The NAS has recognized since 1957 that salt deposits provide the safest possible site for a repository because water can neither get into the repository nor get out of it as a result of the well-known absorptive characteristics of salt. *The Disposal of Radioactive Waste on Land,* Publication 519, NAS (1957), at 3-4. NAS noted that a salt deposit provides a stable, isolating geologic setting because "no water can pass through salt" and its "fractures are self-sealing." *Id.* at 4. Yucca's billions of known fractures are clearly not self-sealing.

In connection with judicial review of WIPP, the D.C. Circuit Court noted that "[s]alt formations ... should prove suitable for disposal of radioactive waste because their low permeability serves to prevent leakage and the plasticity in response to pressure allows fractures in the formations to heal themselves. The salt ... will gradually encase the waste deposited in the underground rooms ... *isolating it* from the accessible environment. *New Mexico v. Watkins,* 969 F.2d 1122, 1125 (D.C. Cir. 1992)(*per curiam)*(emphasis added). For that reason, EPA's 15 millirem/year compliance standard was referred to as the "no migration rule" *Id., citing* 42 U.S.C. § 10141(a); 40 C.F.R. §§ 191.11-.18. That name could of course never be applied to Yucca.

Third, in *NEI,* the Court did not require EPA to extend the compliance period at Yucca to one million years. Rather, it required EPA to extend the compliance period to the time of peak dose/risk, whenever that is expected to occur. It is presumed that this is within one million years, but it could be longer (there is no reason to prejudge this fact in the EPA rule). At Yucca, an untenable peak dose is expected to occur in the accessible environment around the site very shortly after the waste packages fail. That is because Yucca's fractured geology is non-isolating, making the repository more like a septic field than a geologic vault. At WIPP, peak dose never occurs (or it remains at zero) because the geologic medium is perfectly isolating. Another way of stating this is that peak dose occurs at a time period of infinity. And indeed, had EPA specified an "unprecedented" *infinite* compliance period for WIPP, this would not have hindered its licensing or increased its performance uncertainty in any way.

Fourth, at WIPP, the geology was known by DOE and EPA to be so perfectly isolating that *no credit whatsoever was given to man-made waste packages* in that repository's total system performance assessment. *See* 63 Fed. Reg. 27,354-27,369 (1998). A 10,000-year compliance period therefore allowed performance modelers ample time to test the geologic integrity of the site, because it assumed, essentially, that the waste packages had failed in year 1. Nevada would be completely satisfied for DOE and EPA to make the assumption that all of the waste packages at Yucca fail in year 1, and to require modelers to ensure compliance for only a 10,000-year period thereafter. That is because the same analysis done at Yucca as that done at WIPP would show the Yucca repository to grossly fail a compliance standard of 15 millirem/year during the first 10,000 years in that situation. At Yucca, the man-made waste containers provide 100% of the repository's performance during the first 10,000 years, assuming DOE's optimistic assumptions about container life are accepted. But as soon as those containers are presumed to have failed, the repository flunks any compliance standard even remotely similar to that used at WIPP.

In short, EPA's references to the WIPP site as justification for EPA's proposed new approach at Yucca is both highly disingenuous and irresponsible.

XXIV. EPA's Assumptions About Climate and Infiltration are Arbitrary and Erroneous

EPA makes three very broad assumptions about climatic and hydrologic behavior at Yucca. These are that (1) future climatic conditions at Yucca can be bounded by the observed range of conditions over past glacial-interglacial cycles; (2) consideration of climate changes after 10,000 years will introduce uncertainties that do not exist in the period before 10,000 years; and (3) only long-term average responses of the system to changes in infiltration are of relevance. However, as is explained in detail in the report attached in Appendix E, prepared by Dr. M. C. Thorne with input from eminent climatologists Dr. Jonathan Overpeck, Dr. Thomas Wigley, and hydrologist Dr. Howard Wheater, these conclusions are not adequately substantiated by EPA. The full Appendix E must be considered. The effects of different climates after 10,000 years can be better investigated using current and developing techniques that would command substantial support in the scientific community. Therefore, EPA's climatic bounding and infiltration conclusions are at best premature, and at worst unsound. Certainly, these effects are not appropriately the subject of advance specification by rule. *See Climatic Considerations Relevant to the Draft EPA Rule*, by Dr. Michael C. Thorne. Moreover, as Dr. Thorne points out, EPA has unreasonably failed to consider the impact of anthropogenic releases of carbon dioxide on climate and infiltration.

As a result, EPA's assumptions about climate and infiltration over the long term at Yucca are arbitrary and capricious.

Other Problems with the Proposed Rule

XXV. <u>The New Rule Violates the Information Quality Act</u>

EPA's proposed rule violates the Information Quality Act, 44 U.S.C. § 3516 note (Title V, Treasury and General Government Appropriations Act for Fiscal Year 2001, § 515), and OMB's regulations promulgated thereunder, 67 Fed. Reg. 8452 (Feb. 22, 2002). This is because the Cohen Report, which forms EPA's critical scientific basis for the rule, is clearly a "Highly Influential Scientific Assessment" or, at the least, an "Influential Scientific Assessment," that requires under the IQA an adequate peer review, yet no such review was ever conducted. This failure is significant for, as OMB has pointed out, "when an information product is a critical component of rule-making, it is important to obtain peer review before the agency announces its regulatory options so that any technical corrections can be made before the agency becomes invested in a specific approach or the positions of interest groups have hardened." *Id.*

Given the plethora of technical errors and obvious biases in the Cohen Report, which emerged not as a peer reviewed scientific study but an unabashed advocacy piece, this omission was legally and scientifically fatal.

XXVI. <u>The New Rule Fails to Protect Against Plutonium Hazards</u>

On August 3, 2005, the Institute for Energy and Environmental Research (IEER) released a credible scientific report contending that EPA's federally allowed Maximum Contaminant Level ("MCL") level of drinking water contamination by plutonium-239 and other radioactive materials with similar properties is 100 times too high because it is based on obsolete, 1950s science. Nevada's expert Dr. M. C. Thorne was one of the peer reviewers of the study. The report, *Bad to the Bone: Analysis of the Federal Maximum*

Contaminant Levels for Plutonium-239 and Other Alpha-Emitting Transuranic Radionuclides in Drinking Water, authored by Dr. Arjun Makhijani, president of IEER, is attached as Appendix F to these comments. Since plutonium-239 is one of the long-term risks posed by the Yucca repository, Nevada believes that the plutonium MCLs must be revisited by EPA before permitting the proposed Yucca radiation standard to go into effect. Plutonium and other alpha emitters will constitute the largest contributors to long term radiation dose to humans from the repository.

The IEER study bases its conclusion on well-known advances over the past three decades in the scientific understanding of the behavior in the body of plutonium and other alpha-emitting, long-lived transuranic radionuclides. These radionuclides are now widely understood to concentrate near the bone surface and deliver a dose per unit intake that is far higher than previously estimated by EPA. Yet, EPA has thus far refrained from making more stringent its plutonium MCLs.

XXVII. The New Rule Misquotes NAS on Geologic Stability

EPA's proposed rule presumes that the period of geologic stability is 1,000,000 years. While this may prove to be a reasonable limit to the performance assessment, what NAS actually said was that the period of geologic stability was "on the order of 10^6 years." NAS Report at 69. The rule should not absolutely preclude consideration of time scales in excess of 1,000,000 years if justified by considerations of geologic stability and the need to assess long-term performance of the natural barriers.

XXVIII. The New Rule Would be Unconstitutional

All of the above criticisms of EPA's proposed rule highlight what at bottom appears to be a palpable and, indeed, shameless effort to make a nuclear waste repository fit at Yucca Mountain, no matter what. In their own terms, those criticisms raise discrete legal issues that independently call into serious question the validity of the rule as proposed. At the same time, those distinct issues manifest agency action that is profoundly at odds with fundamental norms of the structure of dual sovereignty set out in the Constitution.

Key here is the fact that the Constitution does not create a unified national government, but a federation of sovereign states whose existence preceded the Union. The attributes of sovereignty possessed by the States are "fundamental postulates implicit in the constitutional design." *Alden v. Maine*, 527 U.S. 706, 728-29 (1999). Indeed, the sovereignty of the States is a "separate and distinct structural principle" that "inheres in the system of federalism established by the Constitution." *Id.* at 730. This principle has been elaborated upon and applied in a variety of contexts by the Supreme Court. *See* Robert J. Cynkar, *Dumping on Federalism*, 75 U. COLO. L. REV. 1261, 1278-99 (2004). This constitutional status of the States means that they are entitled to equal dignity and respect as sovereigns. Though the Supremacy Clause mandates that federal power appropriately exercised governs over competing laws or policies of the States, viewed through the Constitution's prism of federalism, the appropriate -- that is, the constitutional

-- exercise of federal authority requires such federal power to be exercised on the basis of generally applicable, rational, facially neutral criteria. Federal power does not extend so far as to allow the imposition of arbitrary burdens on particular States, or on any State.

By straining to make the repository fit at Yucca, EPA has abandoned any pretense of a rational basis for its rule and of equal treatment for Nevada from among other possible sites, thereby infringing Nevada's constitutionally protected rights as a sovereign. Even the federal government's prerogatives under the Property Clause do not override competing constitutional principles, or allow the federalist structure of the Constitution to be so twisted, as to allow this proposed rule to pass constitutional muster. Further analysis of this constitutional issue with respect to Yucca is contained in an attached law review article, Robert J. Cynkar, *Dumping on Federalism*, University of Colorado Law Review, Vol. 75, No. 4 (Fall 2004), which is attached as Appendix F.

XXIX. <u>Tables Highlighting EPA's Infractions</u>

To assist the reader in understanding several key concerns with the proposed rule, Nevada has prepared two tables, drawing from the rule and its supporting materials posted in the rulemaking docket. Table 1 contrasts statements from the NAS Report with those of EPA in the proposed rule, demonstrating that the rule is neither based upon, nor consistent with, key recommendations of NAS. Table 2 contrasts what EPA has said in prior rulemaking with what it now proposes, demonstrating substantial departures from its past statements and policies.

Table 1: Based Upon and Consistent With the Findings and Recommendations of the National Academy of Sciences?

EnPA directs EPA to promulgate a rule "based upon and consistent with the findings and recommendations" of the National Academy of Sciences' technical bases report. The United States Court of Appeals for the D.C. Circuit affirmed this mandate, vacating portions of EPA's prior rule because they were not "based upon and consistent with" the NAS report. *NEI v. EPA*, 373 F.3d 1251 (D.C. Cir. 2004). Yet EPA's new rule again is, in multiple and important ways, thoroughly inconsistent with the NAS's report. This table highlights some of the key inconsistencies.

What the NAS Said	What EPA Says and Proposes to Do
On the importance of peak dose…	
"We recommend… the use of a standard that sets a limit on the risk of individuals of adverse health effects from releases from the repository…(and) **that compliance with the standard be measured at the time of peak risk,** whenever it occurs." NAS Report at 2 (emphasis added).	"**[W]e do not want to place more regulatory emphasis on peak dose projections than can be justified**… In what we see as the best solution to this difficulty, today we are proposing that the individual protection standard consist of two parts, which will apply over different time frames." 70 Fed. Reg. at 49030 (emphasis added).
On appropriate standards…	
[A] general consensus exists among national and international bodies on a framework for protecting the public health that provides a limit of 1 milliSievert (mSv) (100 millirem (mrem)) per year effective dose for continuous or frequent exposures from all anthropogenic sources of ionizing radiation other than medical exposures. A general consensus also appears to exist among national authorities in various countries to accept and use the principle of apportioning this total radiation dose limit among the respective anthropogenic sources of exposure, typically allocating to high-level waste disposal a range of 0.1 to 0.3 mSv (**10 to 30 mrem**) per year. NAS Report at 4 (emphasis added; parentheses in original).	*EPA proposes to allow Yucca Mountain—a single source—to expose people to **350 mrem** a year.*

On the proper performance measure…	
"We recommend that the **mean** values of calculations be the basis for comparison with our recommended standards." NAS Report at 123 (emphasis added).	"NAS did not speak explicitly to any particular performance measure to be used in determining compliance with regulatory standards. This decision was to be left to EPA in the course of rulemaking." 70 Fed. Reg. at 49043. "For the period extending beyond 10,000 years, we propose to use the **median** of the distribution of doses calculated from the performance assessments as the compliance measure… ." 70 Fed. Reg. at 49046 (emphasis added).
On science, modeling, uncertainty, and the relevance of 10,000 years…	
"The current EPA standard contains a time limit of 10,000 years for the purpose of assessing compliance. **We find that there is no scientific basis for limiting the time period of an individual-risk standard in this way.**" NAS Report at 6 (emphasis added). "We see no technical basis for limiting the time period of concern to a period that is short compared to the time of peak risk or the anticipated travel time." NAS Report at 57.	"In formulating an approach to compliance out to the time of peak dose, **we have established 10,000 years as an indicator for times when uncertainties in projecting performance are more manageable**… ." 70 Fed. Reg. at 49029 (emphasis added). *EPA proposes to establish a dose limit of 15 mrem (mean) for the first 10,000-year period of the simulation, and a limit of 350 mrem (median) for the post-10,000-year period.*
"One commonly expressed concern regarding the performance assessment modeling is that it requires simulating performance at such distant times in the future that no confidence can be placed in the results… This argument has been used to support the concept of a 10,000-year cutoff []. **We do not believe, however, that there is a scientific basis for limiting the analysis in this way**." NAS Report at 71 (emphasis added).	"We believe that the most problematic aspect of extending the compliance period to peak dose is the uncertainty involved in making projections over such long time frames… . This remains a critical factor in formulating today's proposal." 70 Fed. Reg. at 49025.
"Implicit in setting a Yucca Mountain standard, is the assumption that EPA, USNRC, and DOE can, with some degree of confidence, assess the future performance of a repository system or even its components. This premise raises the basic issue of whether scientifically justifiable analyses of repository behavior over many thousands of years in the future can be made. **We conclude that such analyses are possible, within the restrictions noted in this report**." NAS Report at 1 (emphasis added).	"[R]egulatory judgment must bridge the gap between what science can show and the unprecedented time frames involved." 70 Fed. Reg. at 49030.

"We conclude that these physical and geologic processes are sufficiently quantifiable and the related uncertainties sufficiently boundable that the performance can be assessed over time frames during which the geologic system is relatively stable or varies in a boundable manner. The geologic record suggests that this time frame is on the order of [one million] years." NAS Report at 9. "In comparison with many other fields of science, earth scientists are accustomed to dealing with physical phenomena over long time scales. In this perspective even the longest times considered for repository performance models are not excessive." NAS Report at 71.	"However, we also believe that over the very long periods leading up to the time of peak dose, the uncertainties in projecting climatic and geologic conditions become extremely difficult to reliably predict and a technical consensus about their effects on projected performance in the licensing period would be very difficult, or perhaps impossible, to achieve." 70 Fed. Reg. at 49029.
More on science, modeling, uncertainty, and the relevance of 10,000 years…	
"Because there is a continuing increase in uncertainty about most of the parameters describing the repository system farther in the distant future, it might be expected that compliance of the repository in the near term could be assessed with more confidence. **This is not necessarily true**... For example, uncertainties in waste container lifetimes might have a more significant effect on assessing performance in the initial 10,000 years than in the performance in the range of 100,000 years." NAS Report at 72 (emphasis added).	"[O]ur view, and the view of many others (including NAS, which should be clear from the above citation: "Because there is a continuing increase in uncertainty…") is that the uncertainties generally increase with time, at least to the time of peak dose. 70 Fed. Reg. at 49026. "We believe rising uncertainties justify adopting a different (higher) dose level." 70 Fed. Reg. at 49032.
On climate…	
"We further conclude that the probabilities and consequences of modifications by climate change… are sufficiently boundable that these factors can be included in performance assessments that extend over this time frame." NAS Report at 9.	"We are concerned about the possibility of over-speculation of climatic change over such extremely long time periods…" 70 Fed. Reg. at 49058.
On seismicity and hydrology…	
"With respect to the effects of seismicity on the hydrologic regime, the possibility of adverse effects due to displacements along existing fractures **cannot be overlooked**." NAS Report at 93 (emphasis added).	"However, we are proposing today that DOE's analysis for seismic events **may exclude the effects of seismicity** on the hydrology of the Yucca Mountain disposal system." 70 Fed. Reg. at 49056 (emphasis added).

Table 2: EPA, Then and Now

In its new rule, EPA departs from consistent past policies in numerous, unexplained, and inexplicable ways. This table summarizes a few of the most egregious examples.

What EPA Has Said in the Past:	What EPA Now Proposes:
On appropriate standards…	
"[N]o regulatory body we are aware of considers doses of 150 mrem to be acceptable." EPA, Response to Comments, 40 C.F.R. part 197, at 3-8 (2001) (emphasis added). "The risk level associated with **70 mrem** is about five times as high the risk level associated with the individual-protection limit. **This is well above the NAS-recommended level and unprecedented in the current regulations of this and other nations for this activity.** It also is significantly inconsistent with the individual protection limit of 15mrem CEDE/yr in our generic standards (40 C.F.R. Part 191). This would result in a risk level at Yucca Mountain that is significantly higher than that at any facility that falls under 40 C.F.R. Part 191." Response to Comments at 4-5 to 4-6 (emphasis added). "A **25 mrem** standard would be "(1) higher than that recommended by the NAS…; (2) inconsistent with [EPA's] generic disposal standards at 40 CFR. part 191…; and (3) even further outside the preferred EPA lifetime risk range." Response to Comments at 4-5 (2001) (emphasis added).	"We would also view **350 mrem/yr** as representing a satisfactory level of performance should it be the "true" value at such long times." 70 Fed. Reg. at 49038. EPA's proposed rule "adds a standard of **350 mrem/yr** to apply beyond 10,000 years within the period of geologic stability." 70 Fed. Reg. at 49061.
On apportionment…	
"The apportionment of the total dose limit among different sources of radiation is used to ensure that the total of all included exposures is less than 1 mSv (100 mrem) CED/yr. Thus, ICRP recommends that national authorities apportion or allocate a fraction of the 1 mSv (100 mrem)-CED/yr limit to establish an exposure limit for SNF and HLW disposal facilities. Most other countries have endorsed the apportionment principle." 66 Fed. Reg. at 32089 (EPA, 2001).	"[W]e would argue that **allocation to a single source at the time of peak dose could be reasonable**, as other contributors currently in the Yucca Mountain area are negligible by comparison." 70 Fed. Reg. at 49041 (emphasis added). *EPA actually proposes to allocate to one source much more than its traditional limit on doses from all sources combined.*

"**70 mrem from one source is too high a proportion of the annual 100 mrem recommended by the NCRP and ICRP** (excluding background, occupational, accidental and medical sources). The apportionment of the total dose limit among different sources of radiation is used to insure that the sum, or total, of all included exposures is less than 1 mSv (100 mrem)." Response to Comments at 4-6 (emphasis added).	
On the appropriate performance measure…	
"We propose a compliance measure we believe is reasonable but still conservative: the **mean** of the distribution of projected doses from DOE's performance assessment… [I]n the case of Yucca Mountain, the **mean** is an appropriate measure." 66 Fed. Reg. at 32125 (2001) (emphasis added).	"For the period extending beyond 10,000 years, we propose to use the **median** of the distribution of doses calculated from the performance assessments as the compliance measure… ." 70 Fed. Reg. at 49046 (emphasis added).
On how to deal with uncertainty…	
"[I]n addressing uncertainties [in quantitative risk assessment] however, EPA generally uses conservative assumptions to ensure that risks are not underestimated." 56 Fed. Reg. 7750 (EPA, February 25, 1991).	"We believe rising uncertainties justify adopting a different (higher) dose level." 70 Fed. Reg. at 49032 (parentheses in original).
On intergenerational equity…	
"With respect to radioactive waste disposal, **we believe the fundamental principle of inter-generational equity is important. We should not knowingly impose burdens on future generations we ourselves are not willing to assume.** Disposal technologies and regulatory requirements are developed with the aim of preventing pollution from disposal operations, rather than assuming that clean-up in the future is an unavoidable cost of disposal operations today. Designing a disposal system, and imposing performance requirements that avoid polluting resources that reasonably could be used in the future, therefore, is a more appropriate choice than imposing clean-up burdens on future generations." 66 Fed. Reg. at 32107 (emphasis added).	*EPA proposes allowing thousands of future generations to face 350 mrem (median) anthropogenic exposures from just one source – a level of exposure over an order of magnitude higher than we allow at present.*

On pre-specifying modeling parameters…	
"Specifying "modeling techniques and assumptions… go(es) well beyond the simple statement of a compliance measure. We did not incorporate a similar level of detail in the Yucca Mountain standards because we believe we must specify only what is necessary to provide the context for implementation that NRC will execute." 66 Fed. Reg. at 32126 (2001).	*EPA now proposes to specify numerous modeling assumptions, including the climate DOE must model, and the engineering, seismic, and volcanic scenarios it must, and must not, consider.*

* * * *

Documents Submitted by the State of Nevada for the Administrative Record in support of the State of Nevada's Comments

	Date	Description
1	1947	Attorney General's Manual on the Administrative Procedure Act Full document: http://www.law.fsu.edu/library/admin/1947cover.html
2	1985/07/01	ICRP Publication 46, Radiation Protection Principles for the Disposal of Solid Radioactive Waste (1985) Full document: http://docket.epa.gov/edkpub/do/EDKStaffItemDetailView?objectId=090007d4800802bb
3	1991/07/01	Protecting the Nation's Ground Water: EPA's Strategy for the 1990's (The Final Report Of The EPA Ground-Water Task Force) Full document: http://docket.epa.gov/edkpub/do/EDKStaffItemDetailView?objectId=090007d480074d8a
4	1995	Principles of Radioactive Waste Management (IAEA 1995) Full document: http://docket.epa.gov/edkpub/do/EDKStaffItemDetailView?objectId=090007d4800802b9
5	1995/10/17	Nuclear Waste Technical Review Board Transcript – Testimony of Steve Brocoum (pp. 152-57)
6	1996/01/30	Statement for the Record, Presentation to the U.S. Nuclear Regulatory Commission, Status of the Civilian Radioactive Waste Management Program by Daniel A. Dreyfus, Director (pp. 15-17)
7	1996/03/27	PowerPoint Presentation by Steve Brocoum (DOE) to Advisory Committee on Nuclear Waste (pp. 3-5, 12-13)
8	1996/04/30	Nuclear Waste Technical Review Board Transcript – Testimony of Lake Barrett (pp. 14-17)
9	1996/04/30	PowerPoint Presentation by Steve Brocoum (DOE) to Nuclear Waste Technical Review Board (pp. 11-13)
10	1997/10/22	Presentation to the Nuclear Waste Technical Review Board Status of the Civilian Radioactive Waste Management Program by Lake H. Barrett, Acting Director (pp. 5-7)
11	1997/12/24	IAEA, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management Full document: http://www.iaea.org/Publications/Documents/Infcircs/1997/infcirc546.pdf
12	1998	Ray Clark, Environmental Radiation Protection Standards for Yucca Mountain: Considerations on Issues Full document: http://66.102.7.104/search?q=cache:hPpgYAb8eZgJ:www.epa.gov/rpdweb00/docs/yu
13	1999/08/01	Public Health and Environmental Radiation Protection Standards for Yucca Mountain, NV: Background Information Document for 40 C.F.R. Part 197 [EPA 402-R-01-004] (Executive Summary, Chapters 2, 9 and 10, and Appendices I, II, and VI) Full document: http://www.epa.gov/radiation/yucca/bid.htm or on Docket OAR-2001-0007-0028 at http://docket.epa.gov/edkpub/do/EDKStaffItemDetailView?objectId=090007d4800762cd
14	2000/02/28	State of Nevada's Comments to DOE's DEIS (Table of Contents only) Full document: http://www.state.nv.us/nucwaste/eis/yucca/ymdeis.htm

	Date	Description
15	2001/06	Evaluation of Potential Economic Impacts of 40 C.F.R. 197 (OAR-2001-0007-0097) Full document: http://docket.epa.gov/edkpub/do/EDKStaffItemDetailView?objectId=090007d4800808e2
16	2001/12	Joint NEA-IAEA International Peer Review of the Yucca Mountain Site Characterisation Project's Total System Performance Assessment Supporting the Site Recommendation Process (Summary, Chapters 1-5, and Appendix 3) Full document: http://ocrwm.doe.gov/documents/ymipr_a/index2.htm
17	2002/12/02	Petitioner State of Nevada's Opening Brief in No. 01-1516 (D.C. Circuit)
18	2004/01/14	Oral Argument Transcript in No. 01-1516 (D.C. Circuit) (pp. 17-33)
19	2005	Kristin Schrader-Frechette, Mortgaging the Future: Dumping Ethics with Nuclear Waste, 11 Science and Engineering Ethics (2005, Issue 4) Full document: http://www.nd.edu/~kshrader/pubs/epa-yucca-oct-2005-art-sci-eng-eth.pdf
20	2005/01/27	EPA's Response to Freedom of Information Act Request by Charles J. Fitzpatrick
21	2005/04/11	Email from John Kessler re: EPRI Report on Yucca Mountain standard licensing options for very long time frames
22	2005/10/04	IAEA Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management Full document: http://www.iaea.org/Publications/Documents/Conventions/jointconv_status.pdf
23	undated	EPA Radon Frequent Questions (from website) Full document: http://www.epa.gov/radon/radonqa1.html

Appendix A

MIKE THORNE AND ASSOCIATES LIMITED

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EXTERNAL MEMORANDUM

Date: 10 November 2005
From: M C Thorne
Subject: International Literature and Health Effects of an Annual Effective Dose of 350 mrem

In the draft EPA standard considerable emphasis is placed on using natural background as a basis for deriving the numerical value of the standard to be applied in the period beyond 10,000 years. However, the arguments for doing this are not well-supported by the references cited. For example, at page 49035 of the draft, the NEA is cited as stating that:

'In view of the way in which uncertainties generally increase with time, or simply for practical reasons, some cut-off time is inevitably applied to calculations of dose or risk. There is, however, generally no cut-off time for the period to be addressed *in some way* in safety assessment, which is seen as a wider activity involving the development of a range of arguments for safety.'

However, it is more helpful to reproduce the full paragraph from the NEA report.

The long timescales addressed in safety assessments arise from the long half lives of some of the isotopes in the waste and the high degree of effectiveness with which deep geological disposal facilities are expected to contain radioactivity – safety studies for deep geological repositories tend to focus on the distant times when releases eventually occur. There are no ethical arguments that justify imposing a definite limit to the period addressed by safety assessments, in spite of the technical difficulties that this can present to those conducting such assessments. It is an ethical principle that the level of protection for humans and the environment that is applicable today should also be afforded to humans and the environment in the future, and this implies that the safety implications of a repository need to be assessed for as long as the waste presents a hazard. In view of the way in which uncertainties generally increase with time, or simply for practical reasons, some cut-off time is inevitably applied to calculations of dose or risk. There is, however, generally no cut-off time for the period to be addressed *in some way* in safety assessment, which is seen as a wider activity involving the development of a range of arguments for safety.

It is also important to recognize what the NEA meant by long timescales in safety assessments. This is made clear at pages 13 and 14 of the cited NEA report. The relevant text is reproduced below.

Over long enough timescales, however, even the most stable engineered materials and geological environments are subject to perturbing events and changes. For example, the possibility of new features and deformation in the repository host rock must be considered over timescales in the order of, say, 10^5 or 10^6 years, no matter how carefully a site is chosen for its stability. These events and changes are subject to uncertainties, which generally increase with time and must be taken into account in safety assessments. Eventually, but at very different times for different parts of the system, uncertainties are so large that predictions regarding the evolution of the repository and its environment cannot meaningfully be made (see Box 1).

As discussed in the next section, arguments for safety can still be made that are likely to be adequate for repository licensing provided a repository is well designed and a suitable, geologically stable site is selected. Well-supported statements regarding the radiological consequences of such a repository can be made for the prolonged period over which the stability of the geological environment can be assured, whereas a less rigorous assessment of radiological consequences is likely to be adequate at later times, on account of radioactive decay and the resulting decreased radiological toxicity of the waste. Nevertheless, an acknowledgement of the limits of predictability of the system in both regulations and in safety cases is important for credibility in the eyes of the public and of other stakeholders.

Thus, the NEA view is that well-supported statements regarding the radiological consequences of a repository can be made for the period over which geological stability can be assured. Beyond that period, a less rigorous assessment is required. It seems clear that the period to be addressed 'in some way' is beyond the period of geological stability and extends indefinitely. The NEA provides no justification for treating the period beyond 10,000 years in this way. Indeed, the only timescales explicitly cited in the above extracts are beyond 10^5 or 10^6 years. Furthermore, in the period for which quantitative assessments can be carried out, 'it is an ethical principle that the level of protection for humans and the environment that is applicable today should also be afforded to humans and the environment in the future'. This does not seem to justify a relaxation of standards at some time within that interval.

At page 49035, a draft ICRP document is cited. Again a selective quotation is used. The statement quoted is that 'Weights can also be assigned according to the time at which the exposure will occur.' However, the EPA fails to state that this quotation is from a section addressing collective dose and not individual dose. Furthermore, the context does not relate specifically to solid radioactive waste disposal. Finally, the quotation is from a consultation document that has not been approved by the Commission and was specifically designated as not for citation. Numerous individuals and groups have commented on this document and it cannot be construed as the agreed position of the ICRP on the issues discussed.

At page 49036, the NEA is further cited. For convenience, the full text is given below, with the selected quotation in bold.

In one of the papers presented at the *timescales workshop* [27], in order to balance ethical and technical considerations and public concerns, a series of time-graded containment objectives is suggested with two target times.

- It is suggested that the initial period of 500 years corresponds to the period of greatest public concern. For this period the objective of total containment is proposed, at least for spent fuel and reprocessed high-level waste in view of the high hazard. This period may overlap with a period of monitoring during which a repository is kept open and unsaturated: in many national programmes, there are proposals for an extended period of monitored, retrievable underground storage. The period may also coincide, at least to some extent, with a phase of relatively complex transient phenomena, including resaturation of the repository and its surroundings. If complete containment can be assured during the transient phase, this can reduce the need to model these phenomena in detail, although the implications of transient phenomena on the longer-term characteristics of the disposal system must be considered.

- In the time period **up to 100 000 years** – the end point roughly corresponding to the crossover point on activity curves – **a dose constraint derived from natural background radiation levels is prescribed.**
- **Beyond some 100 000 years, the proposed objective is that the eventual redistribution of the residual activity by natural processes remains indistinguishable from natural regional variations in radiation levels.**

Reference 27 is:

Long Timescales, Low Risks: Rational Containment Objectives that Account for Ethics, Resources, Feasibility and Public Expectations – some thoughts to provoke discussion, N.A. Chapman, in *The Handling of Timescales in Assessing Post-closure Safety of Deep Geological Repositories.* Workshop Proceedings, Paris, France, 16-18 April 2002, available from the NEA, Paris, 2002.

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Bearing in mind that this quotation is from an individual opinion paper and does not represent a national or NEA view, reference to page 152 of the cited reference shows what Professor Chapman meant by a dose constraint derived from natural background radiation levels. There he stated 'The performance measure appropriate to this period, and to the approach advocated here, would be to have reasonable expectation that any impacts (assuming the same biosphere as today) are less than about 10% of the world-wide variation in normal background radiation (excluding the highly variable radon contribution): a figure of around 0.3 mSv/a is appropriate.'

For reference, 0.3 mSv/a corresponds to 30 mrem per year and not 350 mrem per year. Note also that Professor Chapman excludes radon from his comparison.

At page 49037, the EPA also cites UK guidance relating to the geological disposal of low and intermediate level radioactive wastes. The citation is from paragraph 6.22. The full text of paragraphs 6.21 and 6.22 is given below, with the cited text shown in bold.

6.21 No definite cut-off in time is prescribed either for the application of the risk target or the period over which risk should be assessed. The timescales over which assessment results should be presented is a matter for the developer to consider and justify as adequate for the wastes and disposal facility concerned.

6.22 **At times longer than those for which the conditions of the engineered and geological barriers can be modelled or reasonably assumed,** scoping calculations or qualitative arguments may be used to indicate the continuing level of safety. **Comparisons with the ambient levels of radioactivity in the environment may also be appropriate** (see Requirement R4, Paragraph 6.26). Further comments on assessment calculation timescales are given in Paragraph 8.23.

Paragraph 6.26 imposes the strong additional requirement that 'It shall be shown to be unlikely that radionuclides released from the disposal facility would lead **at any time** [emphasis added] to significant increases in levels of radioactivity in the accessible environment.' Paragraph 8.23 is cited in full below.

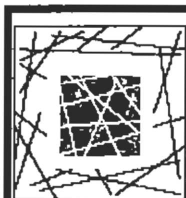
8.23 In general, assessments of the radiological impact of a facility should cover the timescale over which the models and data by which they are generated can be considered to have some validity. In the very long term, irreducible uncertainties about the geological, climatic and resulting geomorphological changes that may occur at a site provide a natural limit to the timescale over which it is sensible to attempt to make detailed calculations of disposal system performance. The timescale over which the Agency will expect to see detailed calculations of risk will therefore depend on the site and the facility and it is a matter for the developer to justify. Simpler scoping calculations and qualitative information may be required to indicate the continuing safety of the facility at longer times.

It should be noted that the compliance criterion in the UK is a target not a limit, i.e. compliance with it is not absolutely required. However, it is set at an annual risk of one in one million per year and is based on a risk factor of 0.06 per Sievert, i.e. it corresponds to a target on annual effective dose of 16.7 μSv (1.67 mrem). This risk target is applied over the whole period for which the conditions of the engineered and geological barriers can be modelled or reasonably assumed. The period is not defined by some degree of increase in uncertainty but applies to the whole period for which the models and data have **some** validity. Even beyond that time, scoping calculations and qualitative arguments may be used. Comparisons with background may be used as a second line of argument and do not stand alone as a criterion of safety. Furthermore, the comparison with background is framed in terms of significant increases in levels of radioactivity and not in terms of doses.

In practice, assessments of deep geological disposal in the UK compute radiological risk out to very long times. This is illustrated by Box 7 from the NEA report cited above, which shows the five timeframes used by UK Nirex Ltd.

Box 7. Illustration of the presentation of a safety assessment based on five time frames

The figure provides an illustration of what is currently envisaged in terms of the assessment and presentation of each of the proposed five time frames in the planned update to the Nirex generic post-closure performance assessment (GPA).



Time frame 1: Waste containers as emplaced

- Institutional control and monitoring (may include long-term storage period)
- Physical barrier intact, containment of radionuclides
- Repository starting to resaturate
- Releases limited to minor diffusive releases through vents and gaseous

Key Performance Indicators:

- Decrease in radionuclide inventory
- Zero flux from near field
- Gaseous releases

Confidence arguments:

- Steel corrosion measurements
- Decay of short-lived radionuclides

Modelling approaches:

- Decay within packages
- Gas generation and Transport

Time frame 2: Physical and chemical barriers evolving

- Repository fully saturated
- Physical barrier may start to break down but waste form limits mobility
- Many radionuclides relatively insoluble, greatest release by diffusion
- Degradation of organics producing complexants
- Gas generation and migration

Key Performance Indicators:

- Decrease in inventory
- Flux from near field
- Gaseous releases

Confidence arguments:

- Comparisons with corrosion of Roman nails
- Cement analogues

Modelling approaches:

- Package-scale model
- Near-field chemistry

Time frame 3: Chemical barrier

- Reducing conditions in near field fully established
- Corrosion causes failure of significant number of packages
- Advective-diffusive release of radionuclides, particularly those which are poorly sorbed
- Gas generation and migration

Key Performance Indicators:

- Flux from near field
- Gaseous releases

Confidence argument:

- Cement analogues
- Maqarin site – limited movement
- of radionuclides away from repository

Modelling approaches:

- Repository-scale near-field model
- Steady-state, regional-scale
- groundwater flow

Box 7. Illustration of the presentation of a safety assessment based on five time frames (cont'd)

Time frame 4: Stable geological barrier

- Most waste packages have failed, offering little resistance to radionuclide migration, therefore the near field is treated as homogeneous
- Migration of radionuclides from near field through far field

Key Performance Indicators	*Confidence arguments:*	*Modelling approaches:*
• Fluxes out of near and far field • Radiological risk • Environmental effects • Comparisons with natural fluxes	• Maqarin site – limited migration • Oklo – retardation • Palaeohydrogeology – geosphere stability	• Homogeneous near-field 'soup' model • Groundwater transport models

Time frame 5: System responding to external change

- Homogeneous near field
- Migration of radionuclides from near field through far field
- Need to consider climate change and hydrogeological changes
- Releases to different climate states

Key Performance Indicators	*Confidence arguments:*	*Modelling approaches:*
• Radiological dose or risk • Comparison with background radiation levels	• Comparisons with natural radiation levels	• Homogeneous near-field 'soup' model • Reference geosphere • Reference biospheres representing different climate states

Note that radiological risk remains a key performance indicator even in Time frame 5.

From the above, it is clear that the EPA has selectively and misleadingly quoted from both overseas and international literature in an attempt to justify setting a standard based on natural background. The further issue that then arises is the potential health implications of setting a compliance standard of 350 mrem per year (recalling that this standard is applied to the median of the assessed doses and that the arithmetic mean (or expectation value) of annual effective dose is anticipated to be about a factor of three higher than the median.

Information on the effects of exposure of humans to ionising radiations is very extensive. Although a principal source of information is epidemiological investigations of the survivors from the atomic bomb explosions at Hiroshima and Nagasaki, many other human populations have been exposed and data from those populations generally corroborate, or are not in conflict with, the data on the atomic bomb survivors. In addition, extensive intact animal and *in vitro* studies have been undertaken to elucidate the mechanisms by which radiation effects are induced. These various studies are regularly reviewed internationally by the United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR) and UNSCEAR reports form part of the basis on which the ICRP develops its recommendations. In the United States, the National Research Council of the National Academy of Sciences also regularly produces reviews of the health risks from exposure to ionising radiations. Its most recent report on this subject was published in 2005 and represents an authoritative current statement of the consensus view on radiation risks at low levels of exposure.[1] For conciseness, that review is subsequently referred to as BEIR VII(2).

The Committee that produced BEIR VII(2) adopted a linear no-threshold (LNT) model for evaluating radiation effects. Thus, the increase in risk is directly proportional to the increment of dose throughout to low dose and dose rate regime. This implies that natural background radiation is considered to be carcinogenic, as is any increment on natural background. The Committee specifically considered whether low doses are substantially more or less harmful than estimated by the linear no-threshold model.

As to whether low doses are substantially more harmful than estimated by the linear no-threshold model, the Committee concluded (page 19):

> In sum, the total body of relevant research for the assessment of radiation health effects provides compelling reasons to believe that the risks associated with low doses of low-LET radiation are no greater than expected on the basis of the linear, no-threshold model.

As to whether low doses are substantially less harmful than estimated by the linear no-threshold model, the Committee stated (page 19):

> ...some materials provided to the Committee suggest that the LNT model exaggerates the health effects of low levels of ionizing radiation...The Committee also does not accept this hypothesis. Instead, the Committee concludes that the preponderance of information indicates that there will be some risk, even at low doses...
>
> Both the epidemiologic data and the biological data are consistent with a linear model at doses where associations can be measured. The main studies establishing the health effects of ionizing radiation are those analyzing survivors of the Hiroshima and Nagasaki atomic bombings in 1945. Sixty-five percent of these survivors received a low dose of radiation; that is, low according to the definition used in this report (equal to or less than 100 mSv). The arguments for thresholds or beneficial health effects are not supported by these data. Other work in epidemiology also supports the view that the harmfulness of ionizing radiation is a function of dose. Further, studies of cancer in children following exposure *in utero* or in early life indicate that radiation-induced cancers can occur at low doses. For example, the Oxford Survey of Childhood Cancer, found a "40 percent increase in cancer rate among children up to [age] 15." This increase was detected at radiation doses in the range 10 to 20 mSv.

In this context, it is relevant to note that 350 mrem per year is 3.5 mSv per year. Thus, exposure for between three and six years at that rate would result in a dose in the range over which a 40 percent increase in the cancer rate in children has been directly observed.

In the Executive Summary to their report (page 28), the BEIR VII(2) Committee states that:

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[1] National Research Council of the National Academies, BEIR VII-Phase 2, Health Risks From Exposure to Low Levels of Ionizing Radiation, The National Academies Press, Washington, D.C.

The committee has developed and presented in the text the committee's best possible risk estimates for exposure to low-dose, low-LET radiation in human subjects. As an example, Table ES-1 shows the estimated number of incident cancer cases and deaths that would be expected to result if a population of 100,000 persons with an age distribution similar to that of the entire US population was each exposed to 0.1 Gy, and also shows the numbers that would be expected in the absence of exposure...

The estimates are accompanied by 95% subjective confidence intervals (*i.e.* random as well as judgmental) that reflect the most important uncertainty sources, namely statistical variation, uncertainty in the factor used to adjust risk estimates for exposure at low doses and dose rates, and uncertainty in the method of transport...

The excess cancer cases per 100,000 of the population from exposure to 0.1 Gy (equivalent to 0.1 Sv or 100 mSv of low-LET radiation) are listed in Table 1.

Gender and Cancer Type	Best Estimate	95 Percent Confidence Interval	
		Lower Bound	Upper Bound
Male: All solid cancers	800	400	1600
Male: Leukemia	100	30	300
Male: Total	900	430	1900
Female: All solid cancer	1300	690	2500
Female: Leukemia	70	20	250
Female: Total	1370	710	2750

Table 1: Excess Cancer Cases per 100,000 of the US Population from Exposure to 0.1 Gy of Low LET Radiation

Corresponding data for excess cancer deaths are given in Table 2.

Gender and Cancer Type	Best Estimate	95 Percent Confidence Interval	
		Lower Bound	Upper Bound
Male: All solid cancers	410	200	830
Male: Leukemia	70	20	220
Male: Total	480	220	1050
Female: All solid cancer	610	300	1200
Female: Leukemia	50	10	190
Female: Total	660	310	1390

Table 2: Excess Cancer Deaths per 100,000 of the US Population from Exposure to 0.1 Gy of Low LET Radiation

Note that the totals listed in Tables 1 and 2 are not given explicitly by the BEIR VII(2) Committee. They have been obtained by summing the values for total solid cancers and leukaemia.

From the above data, and weighting data for males and females equally, the excess risk of inducing cancer in a member of the US population from a dose of 0.1 Gy of low-LET radiation has a best estimate 0.01135 and a 95^{th} percentile range of 0.0057 to 0.02325. The excess risk of causing death from cancer has a best estimate 0.0057 and a 95^{th} percentile range of 0.00265 to 0.0122.

For comparison, a dose rate of 350 mrem (3.5 mSv) per year of low-LET radiation would deliver a total lifetime (80 years) dose of around 0.28 Sv. For low-LET, whole body radiation, the absorbed dose in Gy is numerically equal to the effective dose in Sv, *i.e.* 0.28 Sv is equivalent to 0.28 Gy. Thus, lifetime exposure at the proposed dose limit would correspond to a risk of inducing cancer of 0.032 (range 0.016 to 0.065) and a risk of causing death from cancer of 0.016 (range 0.0074 to 0.034). It should be kept in mind that the arithmetic mean (or expectation value) of the annual effective dose that corresponds to a median annual effective dose is about a factor of three larger. Thus, the expectation value of the lifetime risk of causing death through cancer if the median dose just complies with the dose limit is 0.048 (range 0.022 to 0.102).

Lifetime risks of inducing cancer or causing death through cancer of several percent are very high and cannot be regarded as acceptable. In this context, it is relevant to refer to the most recent, published basic recommendations of the ICRP, ICRP Publication 60[2]. The relevant text relating to dose limits for members of the public is given in summary paragraphs S39 to S41. These are reproduced in full below.

(S39) The scope of the dose limits for public exposure is confined to the doses incurred as a result of practices. Doses incurred in situations where the only available protective action takes the form of intervention are excluded from that scope. Separate attention has also to be paid to potential exposures. Radon in dwellings and in the open air, radioactive materials, natural or artificial, already in the environment, and other natural sources are examples of situations that can be influenced only by intervention. Doses from these sources are therefore outside the scope of the dose limits for public exposure. The conduct of intervention involves occupational exposure and should be treated accordingly.

(S40) The Commission now recommends that the limit for public exposure should be expressed as an effective dose of 1 mSv in a year. However, in special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year.

(S41) In selecting the limit on effective dose, the Commission has sought a value that would be only just short of unacceptable for continued exposure as the result of deliberate practices the use of which is a matter of choice. This does not imply that higher doses from other sources, such as radon in dwellings, should be regarded as unacceptable. The existence of these sources may be undesirable but is not a matter of choice. The doses can be controlled only by intervention, which will also have undesirable features.

Releases of radionuclides from a repository at Yucca Mountain would be expected to give rise to continued exposures, so the principal dose limit value of 1 mSv (100 mrem) per year would be applicable. Effective doses of this magnitude would be only just short of unacceptable. Furthermore, the principal dose limit applies to exposure of individuals from all relevant practices. However, in practice, 'almost all public exposure is controlled by the process of constrained optimisation and the use of prescriptive

[2] 1990 Recommendations of the International Commission on Radiological Protection, ICRP Publication 60, Annals of the ICRP, **21(1-3).**

limits...The dose constraint should be applied to the mean dose to the critical group from the source for which the protection is being optimised. Occasionally, the same group will also be critical for other sources, or if the critical groups are different, each group may incur some dose from the sources for which it is not critical. If the exposures in any critical group are likely to approach the dose limit for public exposure..., the constraints applied to each source must be selected to allow for any significant contribution from other sources to the exposure of the critical group.

In summary, an arithmetic mean dose to the critical group from all relevant practices should be less than 1 mSv per year as such a dose would be only just short of unacceptable. Disposal of radioactive wastes at Yucca Mountain would constitute one such practice. The EPA argues at page 49041 of the draft standard that allocation of 100 mrem per year to a single source (the proposed repository) at the time of peak dose 'could be reasonable, as other contributors currently in the Yucca Mountain area are negligible by comparison.' The EPA further comments that 'to assume (or even to estimate the chance) whether, how, or where other radiation facilities could develop in the far future would require immense speculation about the long-term evolution of government programs, population demographics, and technology.' While this is clearly a reasonable statement, it implies that there is no strong argument against the possibility of such facilities being created. Furthermore, the nature of a geological radioactive waste disposal facility is such that there can be no guarantee, in the long term, that there would be knowledge of the presence of such a facility. Thus, it would not be possible to take the existence of the facility into account when determining the location of future hazardous facilities. In these circumstances, it seems more appropriate to set the standard at a fraction of the principal dose limit, to allow for the possibility of development of such future facilities, noting that remote and sparsely populated areas have been preferred locations for nuclear and other hazardous facilities in the past.

In the context of the discussion of a potential 100 mrem per year dose standard, the EPA draft rule (page 49041) states:

Nevertheless, we have decided not to propose a peak dose standard of 100 mrem/yr because, over the very long term, we believe that natural background levels to which individuals are or could currently be exposed provides a more reasonable context in which to judge the performance of the Yucca Mountain disposal system.

It should be noted that the ICRP set their 1 mSv per year limit based on both considerations of health detriment and on a comparison with natural background. This is described at paragraphs 190 and 191 of ICRP Publication 60.

(190) At least two approaches are possible in choosing a dose limit for public exposure. The first is the same as that used for choosing occupational limits[3]. Assessing the consequences is no more difficult than in the occupational case, but judging the point at which these consequences can reasonably be described as unacceptable is much more difficult. The second approach is to base the judgement on the variations in the existing level of dose from natural sources. This natural background may not be harmless, but it makes only a small contribution to the health detriment which society experiences. It may not be welcome, but

[3] This is acceptability of health consequences to the individual, see ICRP Publication 60, Section 5.3.

the variations from place to place (excluding the large variations in the dose from radon in dwellings) can hardly be called unacceptable.

(191) The consequences of continued additional exposure giving annual effective doses in the range from 1 mSv to 5 mSv...provide no easy basis for judgement, but do suggest a value of the annual dose limit not much above 1 mSv...Excluding the very variable exposures to radon, the annual effective dose from natural sources is about 1 mSv, with values at high altitudes above sea level and in some geological areas of at least twice this. On the basis of these considerations, the Commission recommends an annual limit on effective dose of 1 mSv...

It is noted that the ICRP comparison with natural background excluded the contribution from radon. In contrast, the EPA in their draft rule (page 49037) made comparisons with natural background defined as follows:

For purposes of this discussion, natural background radiation consists of external exposures from cosmic and terrestrial sources, and internal exposures from indoor exposures to naturally occurring radon.

It needs to be pointed out that high exposures to indoor radon are not generally regarded as acceptable and that national programs throughout the world are directed to identifying homes with unusually high radon levels, and to providing advice and assistance on mitigating those levels (see, for example, A Citizen's Guide to Radon: The Guide to Protecting Yourself and Your Family from Radon, U.S. EPA 402-K02-006, Revised September 2005, www.epa.gov/radon/pubs/citguide.html).

In conclusion:

- The international and overseas literature provides no support for arguing that calculations of radiological impact should be assessed against more relaxed standards beyond 10,000 years;
- References cited by the EPA in support of their position either imply or state dose constraints of substantially less than 100 mrem per year applying over timescales of 100,000 years or longer;
- Where natural background has been proposed for use as a basis for assessment, it has been on timescales beyond that of geological stability and/or as one of multiple lines of argument;
- A quotation from the ICRP ostensibly supporting the EPA position is from an unpublished document that has not been approved by the Commission and that was distributed for consultation on the understanding that it would not be cited;
- Furthermore, the text cited does not relate to solid radioactive waste disposal and concerns collective dose not individual dose;
- Application of the draft EPA standard implies that the radiation dose that could be received in three to six years would result in a dose in the range over which a 40 percent increase in the cancer rate in children has been directly observed;
- Application of the draft EPA standard implies a potential lifetime risk of causing death through cancer of up to 4.8 percent;
- The draft EPA standard is a factor of 3.5 larger than the principal dose limit for members of the public recommended by the ICRP;

- That principal dose limit was described by the ICRP as just short of unacceptable for continued exposure and was based both on considerations of health effects and variations in natural background;
- The principal dose limit defined by the ICRP relates to all practices; for a single practice, such as the disposal of radioactive waste at Yucca Mountain, some apportionment of that limit would be expected, as the potential development of future practices in the region involving the use of ionising radiation or radioactive materials cannot be excluded from consideration;
- Whereas the ICRP made comparisons with variations in natural background excluding radon, the EPA made comparisons with the total exposure to natural background including radon;
- High exposures to indoor radon are not generally regarded as acceptable and national programs throughout the world are directed to identifying homes with unusually high radon levels, and to providing advice and assistance on mitigating those levels.

Mike Thorne and Associates Limited

Michael Thorne

Qualifications PhD FSRP
Year of birth 1950
Nationality British

KEY SKILLS

- Radiological protection
- Assessing the radiological safety of disposal of radioactive wastes
- Distribution and transport of radionuclides in the environment
- Expert elicitation procedures
- Probabilistic safety studies
- Development of safety criteria
- Pharmacodynamics

CAREER HISTORY

2001- **Mike Thorne and Associates Limited**

Development of Models for Radionuclide Transfers to Sewage Sludge and for Evaluating the Radiological Impact of Sludge applied to Agricultural Land
Client – Food Standards Agency

Includes a review of literature and the development and implementation of probabilistic models for such transfers.

Development of Biokinetic Models for radionuclides in Animals
Client – Serco Assurance

Development of updated biokinetic models for use by the Food Standards Agency in their SPADE and PRISM modelling systems

Review Studies for the Proposed Australian National Radioactive Waste Repository
Client – RWE NUKEM

Reviews of reports on animal transfer factors and of the potential effects of climate change on the repository plus development of a model for the biokinetics of the ^{226}Ra decay chain in grazing animals.

Development and Application of a Model for Assessing the Radiological Impacts of ^{3}H and ^{14}C in Sewage Sludge
Client – NNC Ltd

Development of a model based on physical, chemical and biochemical principles for the uptake of 3H and 14C into sewage sludge and their subsequent distribution and transport after application of the sludge to agricultural land.

Support for development of the Drigg Post-closure Radiological Safety Assessment
Client - BNFL

Support in the areas of FEP analysis, biosphere characterisation, human intrusion assessment and the effects of natural disruptive events. In addition, provision of advice of future research initiatives that should be pursued by BNFL.

Co-ordination of biosphere research and participation in BIOCLIM
Client – UK Nirex Ltd

Co-ordination of research on climate change, ice-sheet development, near-surface hydrology and radionuclide transport, as well as participation in an international programme on the implications of climate change for radioactive waste disposal.

Review of Parameter Values
Client – AEA Technology/Serco Assurance

Review of biosphere parameter values for use in the ANDRA assessment model AQUABIOS.

Effects of Radiation on Organisms Other Than Man
Client – AEA Technology/Serco Assurance

Study for ANDRA to identify appropriate indicator organisms and develop appropriate dosimetry and effects models for those organisms.

Development of a Database related to Emergency Planning
Client – AEA Technology (Rail)

Identification of relevant international, overseas and national legislation, regulations and guidance, and production of brief summaries of the documents.

Dose Reconstruction for Workers on a Uranium Plant
Client - McMurry and Talbot

Dose reconstruction for the plaintiffs in a case relating to the Paducah Gaseous Diffusion Plant.

Dose Reconstruction for a Worker Exposed to Pu and Am
Client – Pattinson and Brewer

Dose reconstruction for a worker exposed by a puncture wound in the finger while working at a glove box.

1998-2001 **AEA Technology**

Assessment of Remediation Options for Uranium Liabilities in Eastern Europe
Client - European Commission

Studies of remediation requirements relating to mines, waste heaps and hydrometallurgical plant in Bulgaria, Slovakia and Albania.

Evaluation of Unusual Pathways for Radionuclide Transport from Nuclear Installations
Client – Environment Agency

Review of literature and conduct of formal elicitation meetings to determine potential pathways and evaluate their radiological significance.

Revision of Exemption Orders Made Under the Radioactive Substances Act
Client – DETR

Review of requirements for revision and preparation of a draft text for the purposes of consultation.

Support Studies on the Drigg Post-closure Performance Assessment
Client - BNFL

Support in the areas of FEP analysis, biosphere characterisation, human intrusion assessment and the effects of natural disruptive events. In addition, provision of advice of future research initiatives that should be pursued by BNFL.

Development of Models for the Biokinetics of H-3, C-14 and S-35 in Farm Animals
Client - FSA

Review of relevant literature, development of appropriate biokinetic models and implementation in stand-alone software.

Integration of Aerial and Ground-based Monitoring in the Event of a Nuclear Accident
Client - FSA

Desk-based review and simulation study designed to determine optimum monitoring strategies for different types of accidents.

Elicitation of Parameter Values for use in Radiological Impact Assessment Models
Client - FSA

Expert elicitation study to provide distributions of parameter values for use in the suite of assessment models currently used by the FSA for routine and accidental releases.

Biosphere Research Co-ordination and Assessment Studies
Client - United Kingdom Nirex Ltd

Continuation of a programme of work originally undertaken at Electrowatt Engineering (UK) Ltd

Site Investigation and Risk Assessment - Hilsea Lines
Client - Portsmouth City Council

Radiological assessment of a radium-contaminated site.

1987-1998 **Electrowatt Engineering (UK) Ltd**

Evaluation of Inhalation Doses from Uranium
Client - Baron & Budd

Provision of expert witness support in a class action relating to environmental exposure from a uranium plant.

Biosphere Studies Relating to Drigg
Client - BNFL

Provision of advice on time-dependent biosphere modelling for the Drigg low-level radioactive waste disposal facility.

Development of a Siting Policy for Nuclear Installations: Harbinger Project and Follow-up Study
Client - HSE/NSD

Review of existing policy and development of alternatives as a precursor to application to a wide range of installations, not restricted to commercial reactors.

Support to the Rock Characterisation Facility Public Enquiry
Client - UK Nirex Ltd

Preparation of position papers and rebuttals of evidence.

Radiation Doses to an Individual as a Consequence of Working on the San Onofre Nuclear Power Plant
Client - Howarth & Smith

Interpretation of personal and area monitoring data for legal purposes.

Interpretation of Uranium in Urine Data for the Fernald, Ohio Feed Materials Processing Center
Client - Institute for Energy and Environmental Research

Interpretation of urinalysis and lung counting data, and appearance as an expert witness in the associated trial.

Determination of Failure Probabilities for use in PRA
Client - Nuclear Installations Inspectorate

Development of new approaches to the use of Bayes Theorem in defining component failure probabilities for use in PRA when statistics on actual failures are limited.

Review of Inventory Information
Client - UK Nirex Ltd

Review of uncertainties in inventories of individual radionuclides.

ALARP Study of Options for the Treatment, Packaging, Transport and Disposal of Plutonium Contaminated Material
Client - UK Nirex Ltd

Use of multi-attribute utility analysis to establish which option is preferred.

Expert Judgement Estimation of Intrusion Model Parameters
Client - British Nuclear Fuels plc

Project Manager of a study assessing the risks of human intrusion into Drigg radioactive disposal site using expert judgement techniques.

Brainstorming Study of Risks Associated with Building Structures
Client - Building Research Establishment

Participation in a classification study of the health risks associated with buildings including both injuries and disease.

Rongelap Resettlement Project
Client - Marshall Islands Government

Participation in an oversight committee evaluating the radiological safety of Rongelap in the context of resettlement by its evacuated community.

Radiological Consequences of Deferred Decommissioning of Hunterston A
Client - Scottish Nuclear Ltd

Project Manager of a study of the radiological impacts of groundwater transport of radionuclides, releases to atmosphere and intrusion.

Reviews of Safety Documentation
Client - UK Nirex Ltd

Review of safety related documentation for Packaging and Transport Branch.

The Sheltering Effectiveness of Buildings in Hong Kong
Client - Ove Arup & Partners

Project Manager of a study evaluating the shielding effectiveness of all types of building in Hong Kong for volume sources of photons in air and surface deposition sources.

Assessment of the Radiological Impact of Releases of Radionuclides from Premises other than Licensed Nuclear Sites
Client - Ministry of Agriculture, Fisheries and Food

Project Manager of a study to identify representative premises, obtain data on their releases of radionuclides and assess radiological impacts using a new methodology developed for the project.

Assessment of the Radiological Implications of Uranium and its Radioactive Daughters in Foodstuffs
Client - Ministry of Agriculture, Fisheries and Food

Project Manager of a review study of concentrations of uranium and its daughters in foodstuffs, taking local and regional variations in uranium concentrations in soils, sediments and waters into account.

Radionuclides in Sewage
Client - Her Majesty's Inspectorate of Pollution

Project Manager of a study including a desk review on alternative methods of disposal of sewage sludges, interpretation of monitoring data relating to radionuclide discharges from Amersham International to the public sewer system, development of a model for radionuclide transport in sewers, and collection and analysis of effluent, foul water, sediment, sludge and other samples suitable for use in model validation studies.

Accident Consequence Calculations
Client - Nuclear Installations Inspectorate

Project Manager of a study to assess the radiological consequences of various atmospheric releases using the MARC code.

Definition of Threshold Recording Levels for Drums of ILW
Client - UK Nirex Ltd

Project Manager of a study of the implications of post-closure radiological impacts of radioactive waste disposal in defining Threshold Recording Levels for radionuclides in individual waste drums.

Definition of Expert Judgment Exercises Relating to Nuclear Safety
Client - Commission of the European Communities

Project Manager for a study defining expert judgment exercises relating to conceptualisation, representation and input data specification. Included a comprehensive review of available formal expert judgment procedures, and mathematical and behavioural aggregation techniques.

Definition of Research Requirements Relating to the Use of Expert Judgment in Parameter Value Elicitation for Reactor Safety Studies in a UK Context
Client - Nuclear Safety Research Management Unit, HSE

Development of proposals for using combined behavioural and mathematical aggregation procedures in formal elicitations of expert judgment.

Development Priorities for the Drigg Technical Development Programme
Client - British Nuclear Fuels plc

Provision of detailed advice to BNFL on future design options, and research and development priorities, in relation to radioactive waste disposal at Drigg.

Channel Tunnel Safety Studies
Client - Channel Tunnel Safety Authority

Provision of advice and guidance on safety criteria appropriate to the Fixed Link, on the classes of Dangerous Goods that may properly be carried and on the overall characteristics of the proposed Safety Case.

Development of Societal Risk Criteria
Client - Marathon Oil

Interpretation of F-N curves in the context of the offshore oil/gas industry, taking risk aversion into account.

Impacts of Salt Dispersal on Plant Communities
Client - Sir William Halcrow

Evaluation of salt dispersal from a major road in winter in relation to adjacent Sites of Special Scientific Interest.

Offsite Consequence Assessments
Client - Nuclear Electric

Studies of the offsite radiological impacts of atmospheric and liquid releases of radioactive materials from Magnox stations.

Dry Run 3
Client - Her Majesty's Inspectorate of Pollution

Uncertainty and bias studies involving formal expert judgment procedures to develop a conceptual model of those factors and interrelationships which are of significance in determining the post-closure radiological impact of a deep geological repository for radioactive wastes. This project also included advice on data and models to be used for post-closure radiological assessments.

Radiological Assessments of Drigg
Client - British Nuclear Fuels plc

Project Manager for post-closure radiological impact assessments of the Drigg LLW disposal site. Also included specification and development of computer codes relating to the radiological impact of fires, releases of radioactive gases produced by microbial action and metal corrosion, and human intrusion.

Biosphere Co-ordination
Client - UK Nirex Ltd

Co-ordination of the UK Nirex Ltd Biosphere Research Programme from its inception, including requirements definition, technical management of all projects and QA surveillance as the Client's Representative.

Biosphere Support for the Nirex Disposal Safety Assessment Team
Client - AEA Technology

Development of approaches for assessing the radiological impact of releases of radionuclides to the biosphere, plus advice on radiological protection criteria, definition of individual risk, implications of conventionally toxic chemicals in wastes and a variety of other matters.

Evaluation and Radiological Assessment of Liquid Effluent Releases from Various Premises
Client - Her Majesty's Inspectorate of Pollution

Reviews of monitoring data and evaluations of radiological impact, primarily related to Harwell, Aldermaston, Capenhurst and Amersham International.

Evaluation of the Radiological Impact of Overseas Nuclear Accidents
Client - Her Majesty's Inspectorate of Pollution

Studies of the impact of potential overseas nuclear accidents on the UK, with emphasis on survey and monitoring requirements, and the selection of appropriate radiation detection equipment for monitoring.

Bilsthorpe Power Station
Client - British Coal/East Midlands Electricity

Preparation of an Environmental Statement with emphasis on atmospheric dispersion of SO_2 and NO_x.

Gas Generation in Radioactive Waste Disposal Facilities
Client - AEA Technology

Development of a coupled microbial degradation and corrosion model for gas generation in repositories for LLW and ILW.

Effects of Chernobyl on Drinking Water Supplies
Client - Her Majesty's Inspectorate of Pollution

Evaluation of the radiological implications of enhanced concentrations of radionuclides in water supplies in England and Wales subsequent to the Chernobyl accident.

Sea Disposal of Radioactive Wastes
Client - UK Nirex Ltd

Participation in an Environmental Impact Assessment of the proposed resumption of sea-dumping of radioactive wastes.

UK Research Related to Radioactive Waste Management
Client - Her Majesty's Inspectorate of Pollution

Identification of gaps in the UK national research effort related to radioactive waste management.

Research Requirements for Repository Design and Site Investigations
Client - UK Nirex Ltd

Review of research requirements for repository design and site investigations in relation to LLW and ILW disposal in near-surface and deep repositories.

1985 - 1986 <u>International Commission on Radiological Protection, Sutton, Surrey, England</u>

Scientific Secretary responsible for arranging and minuting meetings, administrative arrangements, technical review of reports, editing of the Commission's journal, liaison with other international organisations and public relations.

1979 - 1985 <u>ANS Consultants Ltd, Epsom, Surrey, England</u>

Reviews of data on the distribution at transport of radionuclides in terrestrial and aquatic ecosystems (see publications list).

Development of a dynamic model for radionuclide transport in agricultural ecosystems and implementation of the model on various microcomputer systems.

Photon and neutron shielding studies of radiochemical plant, together with area classification and ALARA studies.

A review of UK use of the criticality code MONK and other approaches to criticality safety assessment.

Radiological and conventional safety aspects of Magnox reactor decommissioning.

Development of metabolic models for inclusion in ICRP Publication 30.

Development of pharmacodynamic models for toxic chemicals.

Review of neutron activation analysis in studies of radionuclide transport in soils and plants.

Experimental studies on radionuclide transport in soils and plants using various photon-emitting radionuclides.

Support for DoE work on probabilistic risk assessment of LLW and ILW disposal.

Review of UK research requirements for HLW disposal.

Post-closure radiological impact assessment of the proposed LLW and ILW facility at Elstow, Bedfordshire.

Development of a generalised biosphere model for use in probabilistic risk assessments of solid radioactive waste disposal.

Initial development of a mathematical model for use in assessing the radiological impact of contaminated groundwater.

Development, computer implementation and comprehensive documentation of a model to calculate the radiological impact of intrusion into radioactive waste repositories.

Development of a general-purpose computer code for solving first-order differential equations using a hybrid Predictor-Corrector/Runge-Kutta method.

Studies on the potential radiological consequences of Magnox reactor accidents.

1974 - 1979 **Medical Research Council Radiobiology Unit, Chilton, Didcot, Oxon, England**

Development of dosimetric and metabolic models for use in ICRP Publication 30.

Studies on the metabolism of plutonium in bone and relationships to blood flow.

Theoretical studies on radionuclide metabolism and dosimetry.

Development of techniques in neutron-induced autoradiography and alpha imaging.

Image analysis studies of plutonium in bone, uranium in lungs, lysosomal inclusions in cells and heterochromatin.

Studies on the clearance of inhaled UO_2.

Alpha spectroscopy in support of toxicity studies with Ra-224.

Data analysis in connection with experimental animal studies on the potential efficacy of neutron therapy using 42 MeV neutrons.

1971 - 1974 **University of Sheffield**

Experimental studies on the reaction $\gamma + p \rightarrow \pi^0 + p$ at photon energies between 1 and 3 GeV, using a linearly polarised photon beam.

PROFESSIONAL ACTIVITIES AND MEMBERSHIP

- Fellow of the Society for Radiological Protection and Immediate Past President
- Member of the Eco-ethics International Union
- Visiting Fellow at the Climatic Research Unit, University of East Anglia

SELECTION OF PUBLICATIONS

A measurement of the beam asymmetry parameter for neutral pion photoproduction in the energy range 1.2 - 2.8 GeV. P.J.Bussey, C. Raine, J.G. Rutherglen, P.S.L. Booth, L. Carroll, G.R. Court, A.W. Edwards, R. Gamet, C.J. Hardwick, P.J. Hayman, J.R. Holt, J.N. Jackson, J. Norem, W.H. Range, F.H. Combley, W. Galbraith, V.H. Rajaratnam, C. Sutton and M.C. Thorne. London Conference (1974) Abstract 997.

The measurement of the polarisation parameters S, P and T for positive pion photoproduction between 500 and 1700 MeV. P.J. Bussey, C. Raine, J.G. Rutherglen, P.S.L. Booth, L.J. Carroll, P.R. Daniel, C.J. Hardwick, J.R. Holt, J.N. Jackson, J.H. Norem, W.H. Range, F.H. Combley, W. Galbraith, V.H. Rajaratnam, C. Sutton, M.C. Thorne and P. Waller. Nuclear Physics, B104, (1976) 253-276.

The polarised beam asymmetry in photoproduction of eta mesons from protons 2.5 GeV and 3.0 GeV. P.J. Bussey, C. Raine, J.G. Rutherglen, P.S.L. Booth, L.J. Carroll, P.R. Daniel, A.W. Edwards, C.J. Hardwick, J.R. Holt, J.N. Jackson, J. Norem, W.H. Range, W. Galbraith, V.H. Rajaratnam, C. Sutton, M.C. Thorne and P. Waller. Physics Letters, 61B, (1976) 479-482.

Aspects of the dosimetry of plutonium in bone. M.C. Thorne. Nature, 259, (1976) 539-541.

The toxicity of Sr-90, Ra-226 and Pu-239. M.C. Thorne and J. Vennart. Nature 263, (1976) 555-558.

Radiation dose to mouse testes from Pu-239. D. Green, G.R. Howells, E.H. Humphreys and J. Vennart with Appendix by M.C. Thorne. Published in "The Health Effects of Plutonium and Radium", Ed. W.S.S. Jee, (J.W. Press, Salt Lake City, Utah, 1976).

The distribution and clearance of inhaled uranium dioxide particles in the repository tract of the rat. Donna J. Gore and M.C. Thorne. In "Inhaled particles IV", Ed. W.H. Walton, (Pergamon Press, Oxford, 1977) pp. 275-284.

Theoretical aspects of the distribution and retention of radionuclides in biological systems. M.C. Thorne. J. Theor. Biol., 65, (1977) 743-754.

Aspects of the dosimetry of emitting radionuclides in bone with particular emphasis on Ra-226 and Pu-239. M.C. Thorne. Phys. Med. Biol., 22, (1977) 36-46.

A new method for the accurate localisation of Pu-239 in bone. D. Green, G. Howells and M.C. Thorne. Phys. Med. Biol., 22, (1977) 284-297.

The measurement of blood flow in mouse femur and its correlation with Pu-239 deposition. E.R. Humphreys, G. Fisher and M.C. Thorne. Calcif. Tiss. Res., 23, (1977) 141-145.

The distribution of plutonium-239 in the skeleton of the mouse. D. Green, G.R. Howells, M.C. Thorne and J. Vennart. In "Proceedings of the IVth International Congress of the International Radiation Protection Association Vol. 2 (Paris 1977).

The visualisation of fissionable radionuclides in rat lung using neutron induced autoradiography. D.J. Gore, M.C. Thorne and R.H. Watts. Phys. Med. Biol., 23 (1978) 149-153.

Lymphoid tumours and leukaemia induced in mice by bone-seeking radionuclides. J.F. Loutit and T.E.F. Carr with an appendix by M.C. Thorne. Int. J. Radiat. Biol., 33, (1978) 245-263.

Plutonium-239 deposition in the skeleton of the mouse. D. Green, G.R. Howells and M.C. Thorne. Int. J. Radiat. Biol., 34, (1978) 27-36.

Imaging of tissue sections on Lexan by alpha-particles and thermal neutrons; an aid in fissionable radionuclide distribution studies. D. Green, G.R. Howells, M.C. Thorne and R.H. Watts. Int. J. Appl. Radiat. Isotopes, 29, 285-295 (1978).

Analytical techniques for the analysis of multi-compartment systems. M.C. Thorne. Phys. Med. Biol., 24, 815-817 (1979).

The initial deposition and redistribution of Pu-239 in the mouse skeleton: implications for rodent studies in Pu-239 toxicology. D. Green, G.R. Howells and M.C. Thorne. Br. J. Radiol., 52, 426-427 (1979).

Bran and experimental colon cancer. M.C. Thorne. Lancet, ii, 13 January 1979, p.108.

Quantitative microscopic studies of the distribution and retention of Pu-239 in the ilium of the female CBA mouse. D. Green, G.R. Howells and M.C. Thorne. Int. J. Radiat. Biol., 36, 499-511 (1979).

Techniques for studying the distribution of alpha emitting and fissionable radionuclides in histological lung sections. T. Jenner and M.C. Thorne. Phys. Med. Biol., 25, 357-364 (1980).

Morphometric studies of mouse bone using a computer-based image analysis system. D. Green, G.R. Howells and M.C. Thorne. J. Microscopy, 122, 49-58 (1981).

A semi-automated technique for assessing the microdistribution of ^{239}Pu deposited in bone. D. Green, G.R. Howells and M.C. Thorne. Phys. Med. Biol., 26, 379-387 (1981).

Radionuclide distribution and transport in terrestial and aquatic ecosystems, Volumes 1 to 6. P.J. Coughtrey, M.C. Thorne et al. A.A. Balkema, Rotterdam 1983-1985.

Dynamic models for radionuclide transport in soils, plants and domestic animals. M. C. Thorne and P. J. Coughtrey. In: Ecological Aspects of Radionuclide Release (Ed. P. J. Coughtrey). British Ecological Society Special Publication No. 3, Blackwell, Oxford, 1983.

Studies on the mobility of radioisotopes of Ce, Te, Ru, Sr and Cs in soils and plants. P.J. Coughtrey, M.C. Thorne, D. Jackson and G.F. Meekings. In: CEC Symposium on the Transfer of Radioactive Materials in the Terrestial Environment Subsequent to an Accidental Release to Atmosphere. Dublin, April 1983.

A study of the sensitivity of a dynamic soil-plant-animal model to changes in selected parameter values. M.C. Thorne, P.J. Coughtrey and G.F. Meekings. In: CEC Symposium on the Transfer of Radioactive Materials in the Terrestial Environment Subsequent to an Accidental Release to Atmosphere. Dublin, April 1983.

Microdosimetry of bone: implications in radiological protection. M.C. Thorne. In: Metals in Bone, N.D. Priest (Ed.) MTP Press, Lancaster (1985), pp. 249-268.

Non-stochastic effects resulting from internal emitters: dosimetric considerations. M.C. Thorne. J. Soc. Rad. Prot., 6 (1986).

Pharmacodynamic models of selected toxic chemicals in man. Vol. 1. Review of metabolic data. M.C. Thorne, D. Jackson and A.D. Smith. MTP Press, Lancaster, 1986.

Pharmacodynamic models of selected toxic chemicals in man. Vol. 2. Routes of intake and implementation of pharmacodynamic models. A.D. Smith and M.C. Thorne. MTP Press. Lancaster 1986.

Generalised computer routines for the simulation of linear multi-compartment systems. D.Jackson, A.D. Smith, M.C. Thorne and P.J. Coughtrey. Environmental Software, 2 (1987), 94-102.

The demonstration of a proposed methodology for the verification and validation of near field models. J-M. Laurens and M.C. Thorne. In: Proceedings of an NEA Workshop "Near-field Assessment of Repositories for Low and Medium Level Radioactive Waste". pp. 297-310. NEA/OECD, Paris, 1987.

Principles of the International Commission on Radiological Protection System of Dose Limitation. Br. J. Radiol., 60 (1987), 32-38.

The origins and work of the International Commission on Radiological Protection. H. Smith and M.C. Thorne. Invest. Radiol., 22 (1987), 918-921.

The potential for irradiation of the lens and cataract induction by incorporated alpha-emitting radionuclides. D.M. Taylor and M.C. Thorne. Health Phys., 54 (1988), 171- 179.

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Post-closure performance assessment: treatment of the biosphere, M A Broderick, M J Egan, M C Thorne and J A Williams, Winnipeg Symposium.

The application of constraint curves in limiting risk, M C Thorne, J. Radiol. Prot., Vol. 17, 275-280, 1997.

The biosphere in post-closure radiological safety assessments of solid radioactive waste disposal, M C Thorne, Interdisciplinary Science Reviews, Vol. 23, 258-268, 1998.

An illustrative comparison of the event-size distributions for γ-rays and α-particles in the whole mammalian cell nucleus, K Baverstock and M C Thorne, Int. J. Radiat. Biol., 74, 799-804, 1998.

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Radiobiological theory and radiation protection, M C Thorne, British Nuclear Energy Society International Conference on Radiation Dose Management in the Nuclear Industry, May 2001.

Development of a solution method for the differential equations arising in the biosphere module of the BNFL suite of codes MONDRIAN, M M R Williams, M C Thorne, J G Thomson and A Paulley, Annals of Nuclear Energy, 29, 1019-1039, 2002.

A model for evaluating radiological impacts on organisms other than man for use in post-closure assessments of geological repositories for radioactive wastes, M C Thorne, M Kelly, J H Rees, P Sànchez-Friera and M Calvez, J. Radiol. Prot., **22**, 249-277, 2002.

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Appendix B

Some Comments on the Proposed Yucca Mountain Compliance Standards

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October 15, 2005

On July 9, 2005, the U. S. Court of Appeals for the District of Columbia Circuit ruled that the compliance period for the proposed Yucca Mountain, Nevada nuclear waste facility be extended from 10,000 to 1,000,000 years. The 1,000,000-year time frame is in keeping with the recommendations made by the Committee on Technical Bases for Yucca Mountain Standards of the National Research Council/National Academy of Sciences in their 1995 report, ***Technical Bases for Yucca Mountain Standards.***[1]

In response to the Court's ruling, on August 22, 2005 the U.S. Environmental Protection Agency (EPA) issued a proposed rule in the **Federal Register** (40 CFR Part 197, *Public Health and Environmental Radiation Protection Standards for Yucca Mountain, Nevada*, **Federal Register**, Vol. 70, No. 161, pp. 49014–49065). The purpose of this document is to comment on one aspect of the proposed ruling - the type of measurement to be used to summarize the results of the computer simulations done by the Department of Energy in the Total System Performance Assessments (TSPA). As seen in the following table, the EPA altered both the type of measurement and the maximum dose used to evaluate scenarios after the first 10,000 years.

Time Span	***Type of Measurement***	***Maximum Dose***
Less Than or Equal to 10,000 Years	Arithmetic Mean	15 mrem/year
Greater than 10,000 Years	Median	350 mrem/year

The use of the arithmetic mean and the 15 mrem/year maximum dose over the first 10,000 years are carried over from the earlier EPA ruling. However, the type of measurement and maximum dose recommended by EPA for the mandated extension beyond10,000 years are dramatically different. The EPA suggests that the median rather than the mean be used as the compliance measurement and that the maximum allowable dose be increased from 15 to 350 mrem/year.

In brief, the EPA argues that the use of the median rather than the arithmetic mean is justified because of the statistical distribution of TSPA simulation results. The EPA further argues that the value of 350 mrem/year is justified because of the high level of uncertainty in the estimates and that the level is similar to the values of current ambient dose levels for neighboring states.

Summary of Conclusions

We believe that the change in the compliance measurement from the mean to the median is not justified on a number of grounds:

[1] "We believe that compliance assessment is feasible for most physical and geologic aspects of repository performance on the time scale of the long-term stability of the fundamental geologic regime—a time scale that is on the order of 10^6 years at Yucca Mountain—and that at least some potentially important exposures might not occur until after several hundred thousand years. For these reasons, we recommend that compliance assessment be conducted for the time when the greatest risk occurs, within the limits imposed by long-term stability of the geologic environment." (NAS, 1995, pp. 6–7).

(1) It is clear that the NAS recommended the use of the mean;
(2) The EPA rejects the arithmetic mean to exclude "very high dose projections resulting from scenarios that are unlikely to occur". However, each TSPA-SR model simulation result has an equal probability of occurring, which means that all scenarios are equally unlikely to occur. It is not clear why any result should be excluded when all results are equally likely. If on the other hand, there are differences in the probability of specific scenarios occurring, the analyst should use the arithmetic mean weighted by the relative probability of occurrence;
(3) The EPA use of the median masks the fact that the distribution of simulation results implies an extremely high probability of non-compliance. At 300,000 years, approximately 42% of the TSPA-SR simulations exceed the 350 mrem/year maximum allowable dose advocated by EPA. With a 42% non-compliance rate, any measure that suggests that the facility is in compliance (as the median does) is at best misleading.[2]

The NAS recommendation concerning the type of measurement

The NAS recommends using the "expected value of the probabilistic distribution".[3] To a statistician—indeed to a scientist—the phrase "expected value" is a term with a very precise mathematical meaning. Quoting from Hogg and Craig, ***Introduction to Mathematical Statistics*** (5th Edition, 1995, page 52), a standard text that is frequently used for the first Junior- or Senior-level mathematical statistics course in statistics departments:

> "The expectation of a random variable is
>
> $$E(X) = \sum_{x} x \times f(x)\text{, in the discrete case}$$
>
> or
>
> $$E(X) = \int_{-\infty}^{\infty} x \times f(x)dx\text{, in the continuous case.}$$
>
> Sometimes the expectation *E*(*X*) is called the *mathematical expectation of X* or the *expected value of X*."[4]

Since the TSPA simulation results all have an equal probability of occurring, the expected value of the set is computed as the sum of the values divided by the number of values that are summed—the arithmetic mean:

$$\bar{X} = \sum_{i=1}^{n} X_i \Big/ n$$

It seems clear that the NAS expected that the arithmetic mean be used to characterize statistical distributions arising from the compliance assessments.

[2] These conclusions apply only to the TSPA-SR and cannot also be assumed to apply to the TSPA-LA.
[3] The phrase is used at least three times in the NAS document—on page 42, on page 65, and finally on page 68.
[4] Essentially the same definition appears in Lindgren, ***Statistical Theory*** (4th Edition, 1993) on page 90 for the discrete case and page 94 for the continuous case.

EPA rejects the arithmetic mean so as to exclude "very high dose projections resulting from scenarios that are unlikely to occur"

The EPA rejects use of the mean as the measure of central tendency for the period after 10,000 years because:

> "we are concerned that the arithmetic mean is too easily influenced by extremes in the distribution, particularly very high dose projections resulting from scenarios that are unlikely to occur. A conservative approach to constructing and evaluating performance scenarios tends to generate high-end results and a simple averaging of these results would drive the arithmetic mean to higher values that would not be as representative overall of the actual distribution of projected doses." (Page 49043)

This quote seems to imply that a high-dose TSPA-SR model realization is somehow less likely than one from the middle of the swarm. This is not true; in fact, any one of the 300 realizations is as likely as any other of the 300. If the EPA had been able to compute the probability associated with a realization, the model would have generated two outputs at a time point: X_i, the dose level for the ith realization and p_i, its associated likelihood. In this case the mean would have been computed as:

$$\bar{X} = \left(\frac{\sum_{i=1}^{n} p_i X_i}{\sum_{i=1}^{n} p_i} \right)$$

This is the probability-weighted mean. The computation of the median would also have become more complicated. In addition to sorting the values into ascending order, it would have been necessary to carry along the associated likelihoods. The median is the value X_k (in the sorted data) for which the quantity $\sum_{i=1}^{k} p_i \Big/ \sum_{i=1}^{n} p_i$ first equals or exceeds 0.5.

When viewed as a probability-weighted mean, the simple arithmetic means gives equal weight to each of the values:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i = \frac{\sum_{i=1}^{n} \frac{1}{n} X_i}{\sum_{i=1}^{n} \frac{1}{n}} \quad \text{(The denominator is 1.)}$$

When written in this more complicated way, one can see that the probabilities associated with each of the values are $1/n$; that is, each realization is as likely as any other.

Although you can't say that this realization, because it is extreme, is by itself less likely than any of the others, you can say that realizations falling into a range of doses are more or less likely than realizations falling into a different, but equally wide, range. For example, it is true that at the 300,000-year point, realizations between 250 and 300 (about 6.1% of the time) are more likely to occur than those between 550 and 600 (about 2.4% of the time).

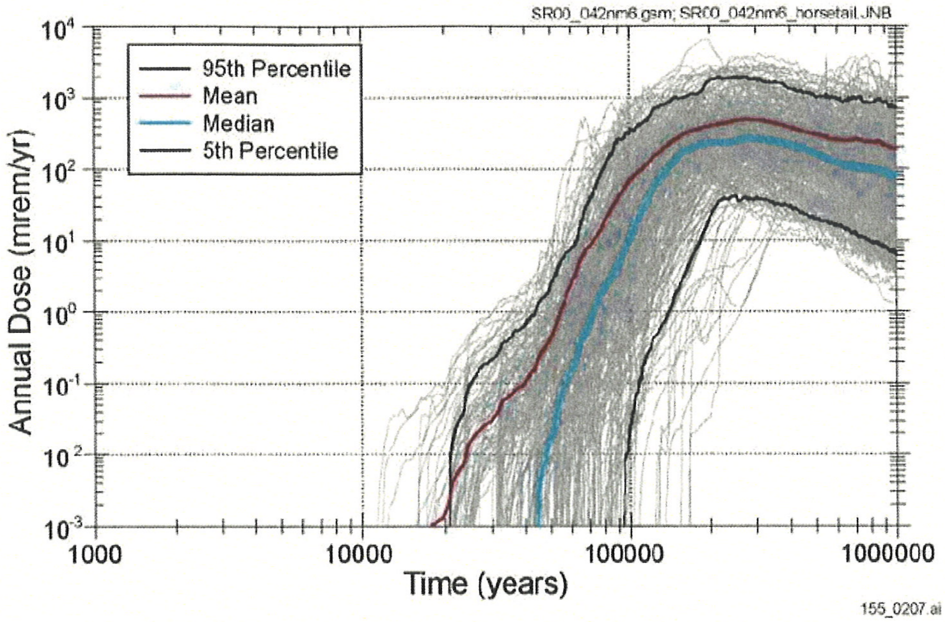
The EPA use of the median masks the fact that the distribution of simulation results implies an extremely high probability of non-compliance

To date, there are several versions of the TSPA model, but our attention will focus on the TSPA-SR (Site Recommendation) model. This model simulates the flow of radioactive materials from drums inside the Yucca Mountain repository to the outside environment (mainly to the water table and from there to the critical group). The ultimate output of the model is the dose (in mrem/year) to which the critical group is exposed and the dose changes over time. Physical processes that are modeled by a large number of equations govern the flow from the repository. The operation of each of these processes depends upon a certain number of physical parameters and the values of these parameters may not be known with certainty. The DOE dealt with this uncertainty in two ways.

If the parameter is important (could have a big effect on the final dose) and if enough is known about the statistical distribution of the parameter, then a random number generator simulating the parameter's statistical distribution is used to generate a potential value for it. On the other hand, it the parameter is less critical to the output or knowledge of the distribution is limited, then a single point estimate is used for the value of the parameter. These single values are chosen to be conservative, that is, to yield higher rather than lower estimates of the dose.[5]

For a single run of the simulation model (or realization), values for each of the statistically modeled parameters were determined by generating a random number from each of the appropriate random number generators and plugging them into the appropriate equations. This means that the parameter values used on one run of the model will not be the same as those used on the next and, consequently, that the output will vary from one run to the next. In the face of this uncertainty, the model is run 300 times and various summary statistics are computed from the model's output. Here is a graph of the output of the 300 realizations of the TSPA-SR model:

[5] To the extent that conservative assumptions (i.e., assumptions leading to higher doses) are used for both the TSPA parameters modeled by distributions and those for which just point estimates are used, the entire set of realizations is shifted upwards (by an unknown amount)— not just the extremely high ones.



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Source: SSPA Volume 2 (BSC 2001 [DIRS 154659]).

NOTE: Summary curves show the 95th, 50th (median), and 5th percentiles, as well as the mean. Results based on the TSPA-SR base-case model.

Figure 2-4. TSPA-SR Base-Case Model: 300 Realizations of Million-Year Annual Dose Histories for Nominal Performance

Note that the time and dose axis are both on logarithmically spaced scales. The light gray lines represent a single realization. The model indicates that there is virtually no discharge for the first 10,000 years and the point of peak discharge occurs between 200,000 and 300,000 years. Also the mean exceeds the median, indicating that the underlying distribution of the simulation results is positively skewed.

Clearly an issue arises when, as in this case, the selection of one type of measurement over another completely changes the conclusions concerning compliance. The use of the median suggests compliance while the mean suggest non-compliance. In these cases, insight into the appropriate measure (if only one measure is allowed) can be obtained by analyzing the distribution of the simulation results. There may be some comfort in using the median if the distribution of simulation results is concentrated about the median. Specifically, if the distribution is so concentrated that a relatively small percent of simulation results exceed the maximum allowable dose.

The EPA proposed rules includes a quotation from the NAS report supporting the criteria of a reasonable level of confidence.[6]

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[6] **Federal Register**, Vol. 70, No. 161, Monday, August 22, 2005, Page 49029

"No analysis of compliance will ever constitute an absolute proof; the objective instead is a reasonable level of confidence in analyses that indicates whether limits established by the standard will be exceeded" (NAS Report p. 71).

The simulation results are not available so it was not possible to precisely compute the percent of the simulation results that exceed the maximum allowable dose. However, it is possible to closely replicate the computation information available from the analysis commissioned by the EPA and conducted by Cohen Associates (Cohen).[7] In that report the authors addressed the uncertainties in the parameters and outputs of the TSPA models. As part of their evaluation, they concluded that the lognormal distribution would be a good first approximation to the statistical distribution of model outputs. To the extent that the lognormal distribution is a good fit to the TSPA model output, it is possible to estimate the fraction of TSPA runs that exceed the proposed dose limit.

The following table is adapted from the Cohen report.[8] Using the 95th percentile and median taken by eye from the plot of TSPA-SR runs, the authors estimated the parameters of the underlying lognormal distribution, *mu* and *sigma*.[9]

		Annual Dose Forecast		***Parameter Estimate***		***Standard***	***Lognormal***
ID	***Year***	***95th Centile***	***Median***	***mu***	***sigma***	***Deviation***	***Mean***
1	21,000	0.0025	n/a	-11.4	3.29	0.56	0.003
2	50,000	2.3	0.02	-3.91	2.88	82.2	1.27
3	70,000	40	0.8	-0.22	2.38	229	13.6
4	100,000	300	10	2.30	2.07	714	85.0
5	200,000	1,600	240	5.48	1.15	778	465
6	300,000	2,000	280	5.63	1.20	1,019	572

mu Estimate of the mean of the logarithms of the annual dose realizations

sigma Estimate of the standard deviation of the logarithms of the annual dose realizations

Assuming that a lognormal distribution is a good first approximation to the TSPA-SR outputs, the fraction of realizations that would exceed 350 mrem/year is computed as follows:

$$\Pr(X > 350) = 1 - \Phi\left(\frac{\log(350) - mu}{sigma}\right)$$

$\Phi(z)$ is the integral of the normal distribution from $-\infty$ to z; it can be computed using the built-in Excel function NORMSDIST( ). The fractions over 350 were computed for each of the six time points appearing in Table 12–1 of the Cohen report. They are presented in the following graph:

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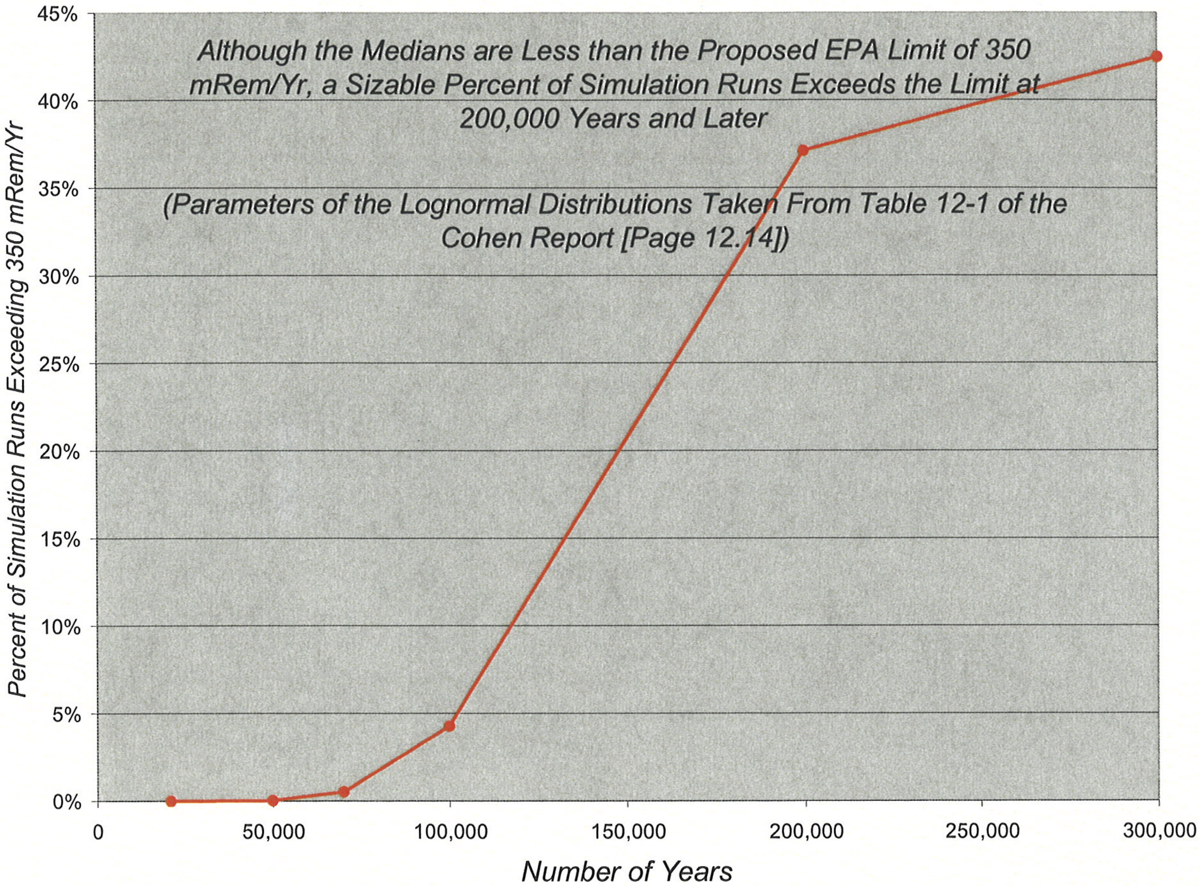
[7] "Revised Final Draft, Assumptions, Conservatisms, and Uncertainties in Yucca Mountain Performance Assessments", Contract Number EP-D-05-002, Work Assignment No. 1-08, Subtask 2, August 8, 2005.

[8] See Table 12–1 on page 12–14 of the Cohen report.

[9] The column labeled "Lognormal Mean" does not appear in Table 12–1, but was computed as $\exp(mu + sigma^2/2)$. Note that this is the theoretical mean of the lognormal distribution; it is not the mean as read from the plot of TSPA-SR results. See Evans, M., Hastings, N., and Peacock, B. **Statistical Distributions**, 3rd Ed., John Wiley, 2000, pages 129–133.



The fraction of runs that exceed the maximum of 350 mrem/year begins to increase at 100,000 years reaching 37% at 200,000 years and 42% at 300,000 years. It seems clear that the fraction of the simulation results over 350 mrem/year would likely exceed 30% to 1,000,000 years. That is, for the 800,000 years from 200,000 to 1,000,000 years the maximum dose would be exceeded at least 30% of the time.

Given the high percent of the simulation results that exceed the maximum allowable dose, it is clear that the use of the median is excluding more than a limited number of low probability events. Thirty-seven and 42 percent of the simulation runs can not be considered low-probability events.

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Trial
(Also provided deposition testimony)

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Deposition: September, 1995;
Trial: October, 1995.

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Deposition: April, 1997
Trial:

Fuller-Austin Insulation Company (Case No. 98–2038)
Trial: October, 1998.
(Also provided deposition testimony)

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Trial: December, 2000
(Also provided deposition testimony)

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Trial: October, 2001
(Also provided deposition testimony)

Fuller-Austin Insulation Company v. Fireman's Fund Insurance Company, et al. (Case No. BC 116835)
Trial: March, 2003
(Also provided deposition testimony)

Babcock & Wilcox Company, et al.
Confirmation Hearing: September, 2003
(Also provided deposition testimony)

Sheila Brown et al. v. American Home Products Corporation (Civil Action No. 99-20593)
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- Deposition
- Testimony

Ezell Thomas, et. al. vs. R.J. Reynolds Tobacco Company, et. al., 1999
- Deposition

Fiberboard Corporation and Owens Corning vs. R.J.Reynolds Tobacco Company, et. al., 1999

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Oglebay Norton Bankruptcy Proceedings, 2004
- Deposition
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Appendix C

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External Memorandum

Date: 10 November 2005
From: M C Thorne
Subject: The Role of Uncertainties in Defining the Proposed Standard

Commentary

The EPA comments (page 49035) 'that having determined that it would be appropriate to propose a numerical peak dose standard for the period of geological stability beyond 10,000 years, we must then determine the appropriate level for that standard. We consider several factors in selecting the level proposed today. First, and most significant, is the issue of uncertainty in long-term projections. Uncertainties are problematic not only because they are challenging to quantify, but also because their impact will differ depending on initial assumptions and the time at which peak dose is expected to occur. Further, the natural tendency in modeling long-term processes is to introduce additional conservatisms to help ensure that actual performance will be no worse than projected performance.'

Based on this comment, the EPA (page 49035) reiterates its earlier view that 'setting a strict numerical standard at a level of risk acceptable today would ignore this cumulative uncertainty and the extreme difficulty of using highly uncertain assessment results to determine compliance with that standard'.

Thus, the EPA seems to be arguing for a much laxer standard after 10,000 years on two grounds relating to uncertainty. The first is that the increasing uncertainty justifies allowing for the possibility that the assessed dose would be greater than the standard imposed up to 10,000 years after closure and that this allowance can be achieved by specifying a laxer standard after 10,000 years. The second is that increasing uncertainties after 10,000 years will require greater use of cautious or bounding assumptions, so that the assessed doses will be higher than those that would have been estimated had it been possible to make realistic assumptions, such that compliance with a laxer standard will actually imply compliance with some stricter standard.

While there are various sources of uncertainty associated with the repository system that increase with time (S. Cohen & Associates, 2005), it is important to recognize that:

- Some of the uncertainties are associated with future human actions and are addressed through prescriptive rule making, e.g. by defining the characteristics of the exposed group;
- Many of the uncertainties relate to the behavior of the repository system, but do not affect strongly the radiological impacts associated with the system;
- The various uncertainties cannot be combined in a simple fashion, and their combined effect may not increase significantly with time, even if individual uncertainties increase with time.

In evaluating the Draft EPA Rule, it is important to recognize that the EPA is proposing that compliance with the draft standard should be demonstrated by undertaking probabilistic calculations with the DOE Total System Performance Assessment (TSPA) model. In that model, multiple realizations of the future performance of the proposed disposal system are evaluated. Each realization is characterized by parameter values selected from uncertain distributions. Thus, the results obtained from each realization differ (see Figure 1[1]) and it is the ensemble of such results that has to be compared with the standard.

[1] Although illustrations are presented from existing TSPA calculations in this memorandum, it is important to emphasize that judgment on the suitability of the Draft EPA standard cannot and should not be based on the quantitative results that have been presented to date. It cannot be known in advance what distributions of results will arise from the TSPA calculations undertaken for Licence Application, nor can any assumptions be made as to the degree to which those calculations will be based on cautious (or non-cautious) conceptual models and parameter value distributions.

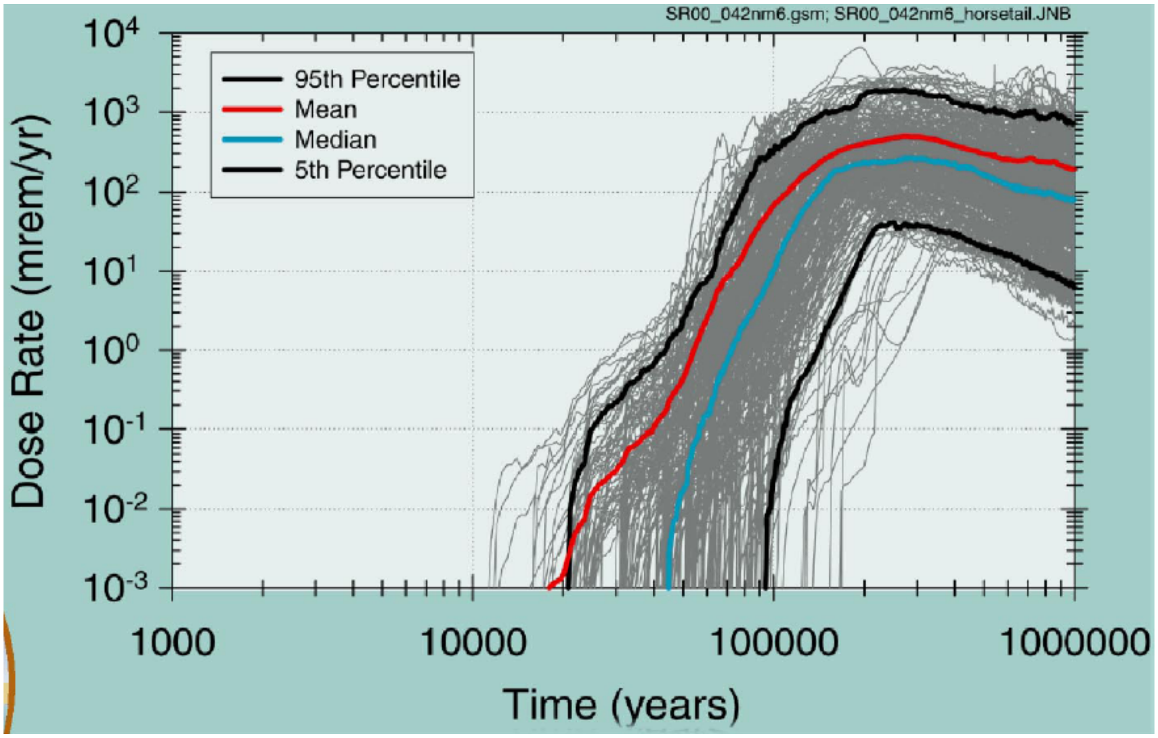

Figure 1: TSPA-SR One-Million-Year Dose Histories for Nominal Case (as Figure 12.1 of S Cohen & Associates, 2005, but reproduced from SSPA, Volume 2, Figure 3.1.2-1)

Figure 1 shows various statistical measures of the distribution. These are the arithmetic mean, median, and 5th and 95th percentiles. Results from the individual realizations are also shown. For the period up to 10,000 years, the EPA is proposing that the arithmetic mean value should be compared with a dose limit of 15 mrem, whereas beyond 10,000 years the EPA is proposing that the median value should be compared with a dose limit of 350 mrem. From Figure 1, it will be seen that the arithmetic mean value exceeds the median value at all times of interest and, in particular, at the time of peak dose. This result is general for any distribution that is positively skewed. The median value at any specific time is obtained by rank-ordering the results obtained from the individual realizations at that time and selecting the value of the mid-ranking result. Thus, if there were 300 realizations, the median would lie between the values of the 150th and 151st after they had been rank ordered by value. In contrast, the arithmetic mean is defined as the sum of all the results at a particular time divided by the number of realizations.

S Cohen & Associates (2005; page 12-5) comment that an advantage of the arithmetic mean as a measure of central tendency is that, 'for almost any form of underlying population distribution, normal or not, the arithmetic mean is an unbiased estimate of the true mean of the population distribution.' Here, the true mean is the value of the arithmetic mean that would be obtained from an infinite number of realizations. However, they also consider that 'the arithmetic mean often is a poor measure of central tendency for environmental data…In any run of the performance assessment model with several hundred realizations, there may be several extreme values…the arithmetic mean is not robust because a single unusual value can cause a very large deviation of the arithmetic mean from the center of the distribution of values in the data…When applied to data with positive values that are skewed to the right, the arithmetic mean usually lies above the median value. In some cases, the arithmetic mean may exceed 95% of the values. In extreme cases, the arithmetic mean may exceed all values other than the single highest value in the data.'

S Cohen & Associates (2005; page 12-6) also comment that the 'median is a very robust estimator of the center of a distribution of values. This estimator is robust because there can be a substantial number of unusual values, either high or low, yet the median is not distorted by these unusual values.'

Although the median can be a more robust measure of central tendency than the arithmetic mean, often implying that a well-defined value will be obtained from a smaller number of realizations[2], this does not make it an appropriate measure for comparing with a regulatory standard. Because the arithmetic mean is an unbiased estimator of the true mean, irrespective of the number of realizations, it provides a direct estimate of the expectation value of the dose, i.e. each realization contributes in direct proportion to the dose associated with it. In contrast, two distributions of values of dose can have identical median values, but very different potential health implications. For example, the set of 11 doses {0.5, 1.0, 1.2, 1.3, 1.4, 1.8, 1.9, 2.0, 2.1, 2.2, 2.3} has a median of 1.8. This is identical to the median of the set {0.5, 1.0, 1.2, 1.3, 1.4, 1.8, 2.5, 3.8, 6.2, 9.3, 12.5}. However, the latter distribution includes much higher values above the median. Effectively, use of the median as a measure of performance totally discounts the absolute magnitude of values higher than the median. As radiation protection regulation is based on the concept of a linear no-threshold relationship between dose and effect at low doses and dose rates, the arithmetic mean dose gives an unbiased estimate of the expectation value of health detriment at any time, whereas the median dose does not have a well-defined relationship to health detriment.

Rather than arguing that there is a problem with the arithmetic mean because it is not a robust measure of central tendency, it is more appropriate to argue that the arithmetic mean is an appropriate unbiased measure of repository performance and that it may (or may not) require more realizations to achieve a converged estimate of the mean than of the median, depending upon details of the shapes of the underlying distributions from which parameter values are selected. Furthermore, the insensitivity of the median to unusually high values is a weakness for safety assessment purposes, in that it specifically fails to give any recognition to those particular parameter value combinations that are prejudicial to repository safety. Indeed, considering Figure 1, there is a strong argument that, if some percentile of the distribution of results is to be used rather than the

[2] It should be noted that the value of the median is not necessarily less uncertain than the value of the arithmetic mean for a fixed number of realizations. Indeed, for a normal distribution, the standard error on the median of a sample is slightly more than 25% greater than the standard error on the sample mean. However, the median is less uncertain for distributions that exhibit significant tails.

arithmetic mean, that percentile should not be the 50th (i.e. the median), but some higher value such as the 95th, so that situations prejudicial to safety are expressly addressed, but without going to the non-robust extreme of considering the single worst realization.

It might be argued that the realizations giving rise to high doses and, therefore, lying at high percentiles of the distribution, should be disregarded because they represent unrealistic combinations of parameter values. However, EPA cannot know *a priori* that this will be the case. Any cautious assumptions adopted by the DOE could equally well affect all realizations and there is no intrinsic reason to prefer one realization to another. Furthermore, until the TSPA-LA is presented, it cannot be determined what, if any, cautious assumptions will be adopted by DOE. It is, of course, appropriate for DOE and other interested parties (e.g. NRC) to examine the results from assessment calculations to determine whether the individual realizations and the overall sets of realizations are appropriate for use for compliance purposes. Such an examination might result in the exclusion of individual realizations or the requirement to rerun the calculations with modified models or altered sampling of the input parameter values, e.g. to reflect accurately any dependencies between the various parameters. However, once this iterative evaluation of the quality of the assessment has been completed, there should be no reason to give preference to one realization over another in the final evaluation of compliance. On this point, it is important to emphasize that high dose outliers are potentially important indicators of performance that need to be scrutinized closely. A key issue in safety assessment is to identify potential circumstances that could be prejudicial to safety and then to determine whether any actions can be taken to prevent or mitigate such circumstances. High dose outliers are such potentially important indicators of performance. Although not directly relevant to the issues addressed in this memorandum, it is important to emphasize that the safety of the proposed Yucca Mountain facility needs to be evaluated against the full range of results obtained and not just against some central tendency in those results, irrespective of how that central tendency is defined.

It should also be noted that if the median was used as a basis for compliance with a constant standard from the time of repository closure onward, an increase in uncertainty with time would not, in itself, necessarily result in greater difficulty in complying with the standard. However, for positively skew distributions, as typically occur in assessment studies, if the median remains constant in time and the uncertainty increases, the arithmetic mean will increase, so compliance with a constant standard will become more difficult with increasing uncertainty. This is illustrated in Figure 2.

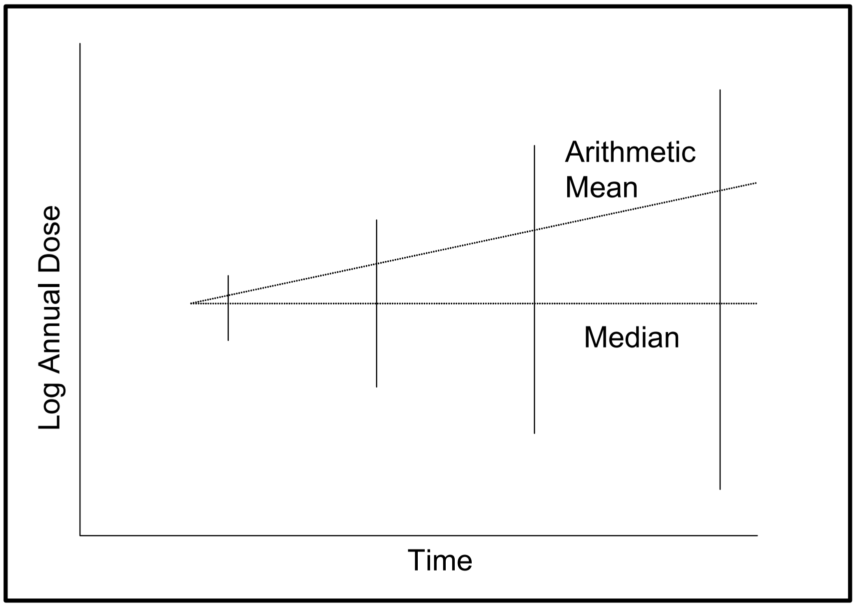

Figure 2: Relationship between the Median and Arithmetic Mean for a Positively Skew Distribution

Here a lognormal distribution underlies the range of variation at each time. As time increases, the range of variation increases, but because the range increases both to lower values and to higher values, the median can remain constant (imagine the vertical distance of each value from the median being multiplied by a constant scale factor greater than one as you move from one time to the next). Interestingly, the arithmetic mean value in this system does not remain constant, but increases, because it reflects the magnitudes of the individual values and not just whether they are above or below the median value. This distinction is general for positively skew distributions and can be quantified for particular examples. Thus, for the example of the commonly used lognormal distribution:

$$\mu = \exp(M + \sigma_g^2/2)$$

where μ is the arithmetic mean, M is the median and σ_g is the geometric standard deviation. Thus, for constant median M, the value of the arithmetic mean increases as the degree of uncertainty (measured by the magnitude of σ_g) increases.

On this basis, the use of the median as a compliance measure diminishes the importance of changes in uncertainty with time relative to use of the arithmetic mean. However, it is not accepted that the uncertainty in performance at Yucca Mountain does increase substantially with time. This is demonstrated by a careful consideration of Figure 1. Both the median and 95th percentile can be seen at 50,000 years, where they differ by three orders of magnitude. At the peak, around 200,000 years, they differ by only one order of magnitude and this difference persists through to the end of the simulation.

Thus, no justification for an increase in uncertainty with time can be argued from this figure.

Similar results arise for a case with early waste package failure, as illustrated in Figure 3.

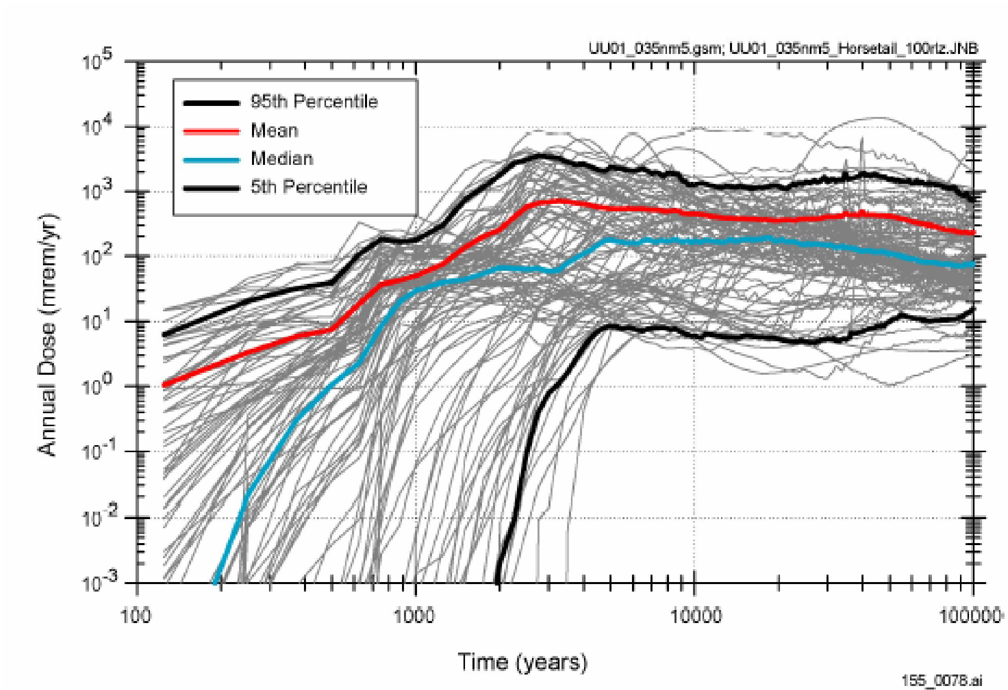

Figure 3: Figure 3.2.2-12 from Volume 2 of the SSPA, illustrating a Case with the Base Case Seepage Model and Neutralized Waste Packages and Drip Shields

Note that, in this case, the uncertainty decreases until it reaches a fairly constant value from approximately 4,000 years onward.

However, care should be exercised in interpreting this type of presentation. This is because the figures confound uncertainty in timing with uncertainty in the magnitude of the peak dose that arises. This is illustrated schematically in Figure 4.

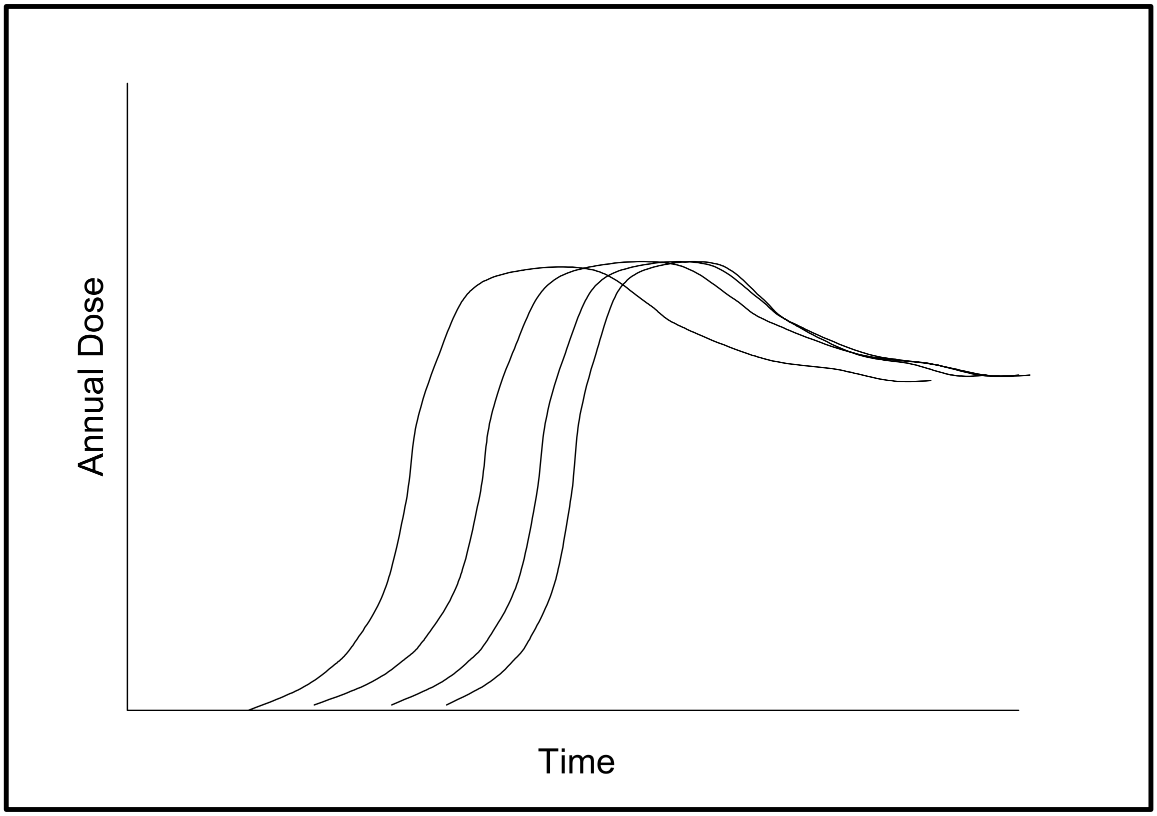

Figure 4: Illustrative Patterns of Variations in Annual Dose with Time

In Figure 4, all the dose-time curves are identical in shape. However, they have been moved relative to each other along the time axis and either stretched or compressed in time relative to the reference curve. Thus, there is no difference in the peak dose received, i.e. in this hypothetical illustration there is no uncertainty in the peak dose. However, comparing the curves in respect of the annual dose at a particular time, there is no uncertainty at early times, because all the doses are zero, the uncertainty then increases, because the curves rise at different times, and then decreases as the curves converge. Similar effects, though less extreme, can be seen in Figures 1 and 3. Thus, in Figure 1, the uncertainty between 10,000 and 100,000 years is largely due to the time at which the increase in dose occurs and only secondarily due to the magnitude of that increase. Uncertainties in timing give rise to an effect termed ‘risk dilution’. It is noted that this effect is not addressed in the Draft EPA Rule. As a compliance standard is being set through to the period of peak dose, it would be appropriate to discuss whether that standard should apply to the mean (or median) value of the peak doses from the various realizations or the peak value of the mean (or median) dose from all realizations as a function of time.

The shape of the uncertainty envelope can also be affected by the inclusion of two distinct failure modes in the same plot. This is illustrated by Figure 5.

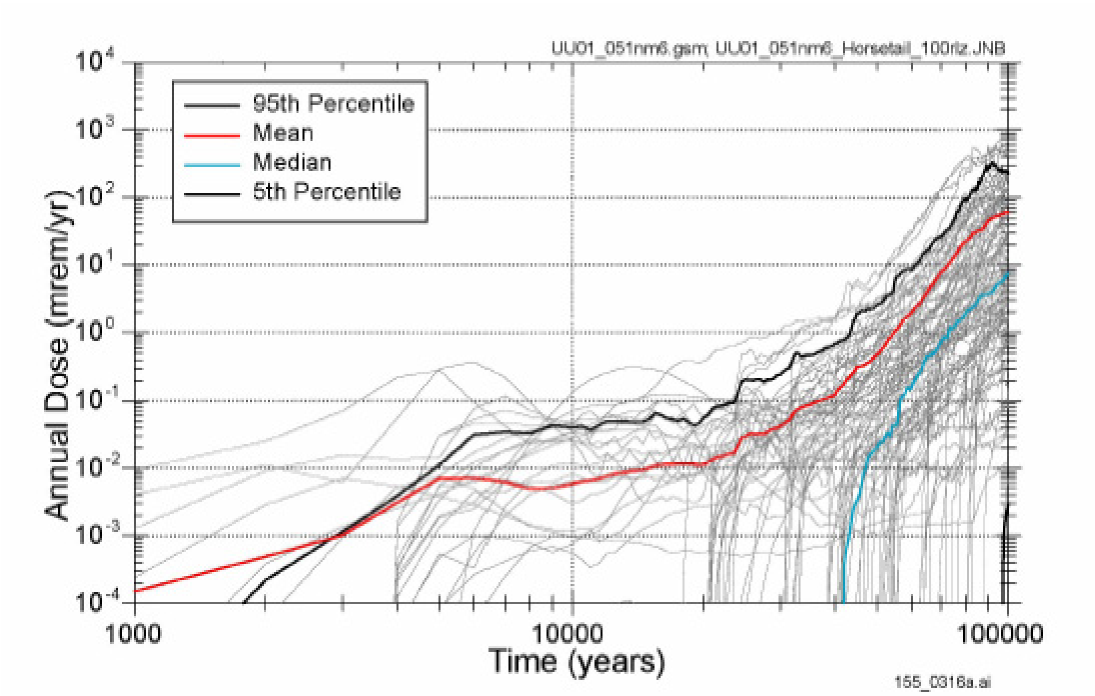

Figure 5: Figure 3.2.5.4-1 from Volume 2 of the SSPA, illustrating the Sensitivity of Annual Dose to Additional Uncertainty associated with Early Waste Package Failures due to Improper Heat Treatment

In Figure 5, the uncertainty to 40,000 years is very large (note that the median does not appear on the figure and the mean is higher than the 95th percentile over the first 2,500 years. Beyond 40,000 years there is a transition from a system dominated by releases from the waste packages that failed early to a system dominated by more general waste package failure. Beyond that time, as it becomes increasingly likely that the majority of the packages have failed, the uncertainty range decreases and, by 100,000 years, the difference between the median and the 95th percentile is only about a factor of twenty.

It should also be noted that 10,000 years does not represent a time at which there is necessarily a qualitative change in system performance. Thus, in Figure 1, the qualitative change occurs beyond 20,000 years. In Figure 3, there is no qualitative change and system performance remains much the same from 2,000 to 100,000 years. In Figure 5, the qualitative change occurs beyond 20,000 years, when early package failure becomes dominated by more general package failure.

S Cohen & Associates (2005) argue for an increase in uncertainty with time based on Figure 12-4 of their report. In relation to that figure they state (page 12-14) that the ‘uncertainty in the forecast increases dramatically over time’. However, this is because they have expressed the uncertainty in absolute terms, rather than in relation to the median dose. This is demonstrated by the data in Table 1. These are taken from Table 12-1 of S Cohen & Associates (2005) and underpin their Figure 12-4.

Year	**Annual Dose Forecast (mrem y^{-1})**		**Ratio of 95th Percentile to Median**
	Median	**95th Percentile**	
21,000	-	0.0025	-
50,000	0.02	2.3	115
70,000	0.8	40	50
100,000	10	300	30
200,000	240	1600	6.7
300,000	280	2000	7.1

Table 1: Median and 95th Percentile Dose Estimates given in Table 12-1 of S Cohen & Associates (2005)

Thus, a correct statement is that the absolute magnitude of the uncertainty increases with time, but the relative degree of uncertainty decreases.

A further consideration in respect to uncertainty is shown in Figure 6.

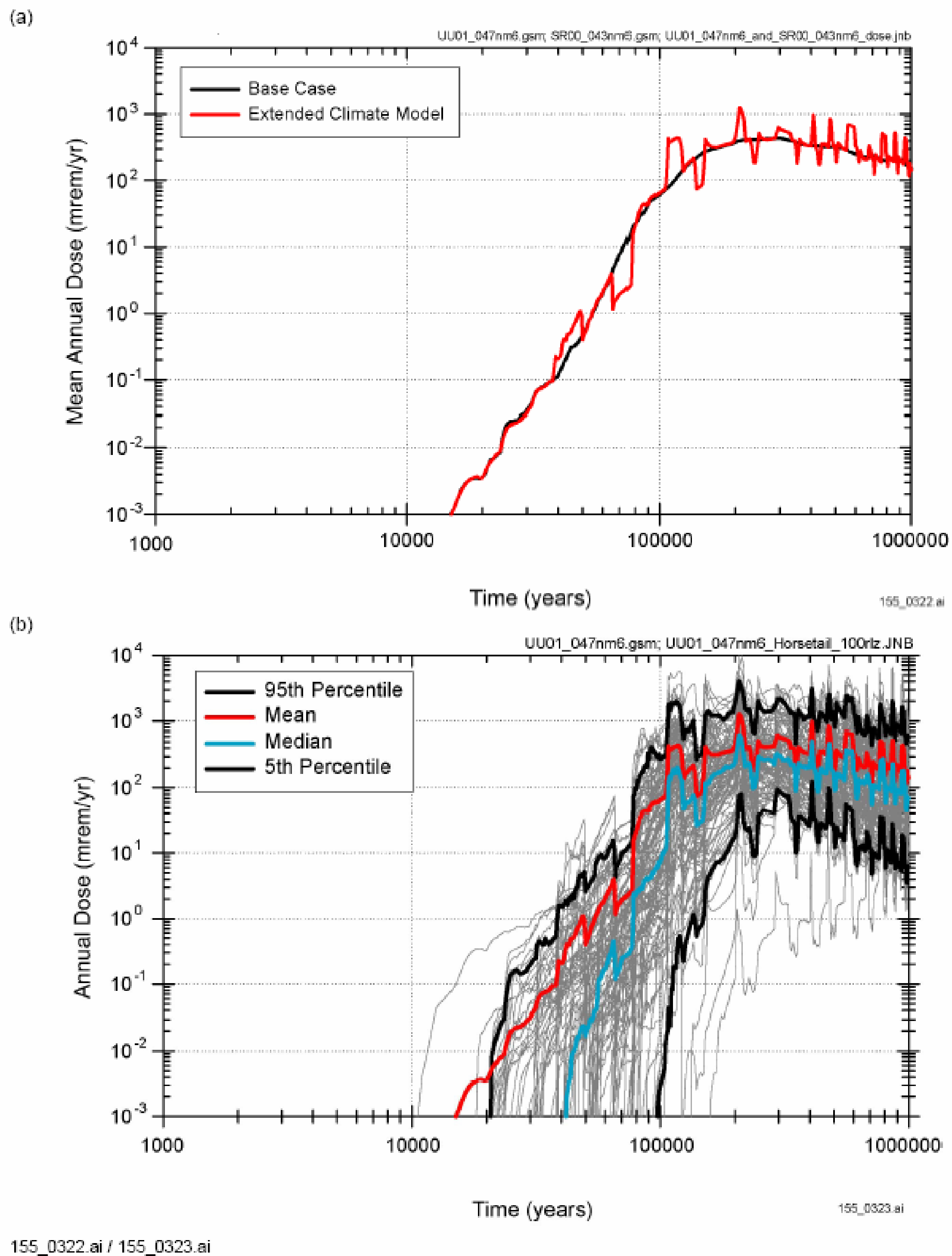

Figure 6: Figure 3.2.1-1 from Volume 2 of the SSPA, illustrating Annual Dose Histories from the Extended Climate Model and the Base Case

The TSPA-SR base-case climate model was developed for the 10,000 year regulatory period and had no changes of climate state after 2,000 years. An extended climate model for the period from 10,000 years to one million years was also developed. In this model, six climate states were determined for the post-10,000 year period. The extended base-case climate model is the same as the base-case climate model until 38,000 years, i.e. there is no change in climate state from 2,000 years to 38,000 years, which is when the first glacial period is estimated to occur. The next glacial periods occurs at 106,000 years and 200,000 years. Glacial periods are 8,000 to 40,000 years in duration and recur approximately every 90,000 years, on average. Figure 6, part a compares the mean data from the base case run to one million years, i.e. with no climate change beyond 2,000 years, and the extended climate model. Comparison of these mean curves when long-term climate change is taken into account reveals increased uncertainty, reflected in the more variable nature of the mean annual dose in the extended climate model case. However, Figure 6, part b shows that this is not the full story. The spikiness arises because the changes of climate are represented as discrete switches between one climate state and another at pre-defined, identical times in all realizations. In practice, climate changes continuously. Furthermore, even if the process is simplified in terms of instantaneous switches, e.g. by arbitrarily defining boundaries between the states in terms of mean annual precipitation, the timing of those changes is uncertain and should not be the same in every realization. Both of these considerations would smooth the dose curve from that shown for the extended climate model case. Thus, the increased uncertainty that might be inferred from Figure 6 is an artifact of the modeling procedure used and does not relate to the actual system being simulated.

There remains the consideration as to whether extension of the calculations beyond 10,000 years involves the use of more cautious assumptions. It should first be noted that the various calculations described above and others presented in the SSPA were undertaken by running calculations defined for 10,000 years through to either 100,000 years or one million years, i.e. there were no changes in assumptions at 10,000 years. The exception is the climatological modeling illustrated in Figure 6. However, in that case changes of climate state had been defined in the period up to 10,000 years and an extended sequence of changes of state was defined for the period through to one million years.

Although it seems plausible to argue that uncertainties in system performance could increase with increasing time into the future, this is not borne out by the results reported in the SSPA and it is of interest to examine why this is the case. For this purpose, it is appropriate to consider the following components of the system:

- Infiltration as determined by climatic conditions;
- Entry of water into the drifts;
- Corrosion of drip shields and waste packages;
- Percolation of water into waste packages and leaching of radionuclides;
- Transport of radionuclides through the unsaturated zone;
- Transport of radionuclides through the saturated zone;
- Abstraction of radionuclides from a groundwater well, transport in the biosphere and radiation exposes of the Reasonably Maximally Exposed Individual (RMEI).

It is relevant to note that the next one million years is assumed to be an appropriate period over which geological stability of the Yucca Mountain area can be assumed. Thus, changes in hydrogeology, hydrogeochemistry, radionuclide transport and radiological impacts can be evaluated within a well-defined geometrical and stratigraphic framework (setting aside igneous and seismic events, as these are addressed separately).

The infiltration of water into the unsaturated zone at Yucca Mountain will be determined by changes in climate. The DOE has assumed that future climatic conditions at Yucca Mountain will lie within the envelope of climatic conditions that has occurred over the Quaternary (approximately the last 1.6 million years). On this basis, the DOE has identified a set of potential future climate states and has used these in modeling (see Figure 6). Radiological impacts tend to be increased when infiltration is increased, as in the glacial state.

In their report, S Cohen & Associates (2005, page 1-11) state that 'the possibility of anthropogenic climate forcing has also not been included in the modeling of future climates. This could introduce a significant measure of uncertainty to long-term dose predictions.' The reader could easily misunderstand this statement and think that 'long-term' referred to the period beyond 10,000 years. However, this clearly cannot be the case. Even without the imposition of controls on fossil fuel usage, limitations on available resources imply that rates of utilization similar to those occurring at the present day cannot persist for more than a few centuries. Thus, atmospheric concentrations of carbon dioxide are likely to peak on a similar timescale. Although there is some inertia in the climate system in responding to enhanced greenhouse-gas concentrations, largely because of the large thermal inertia of the oceans, various experiments with atmosphere-ocean general circulation models (AOGCMs) and Earth Models of Intermediate Complexity (EMICs) have demonstrated that global warming is likely to peak soon after atmospheric carbon dioxide levels reach their maximum concentration. Thus, the most extreme warming change to the global climate system due to anthropogenic effects is likely to occur on a timescale of a few hundred to, at most, a few thousand years. Thereafter, with a reduction in fossil fuel usage, atmospheric carbon dioxide concentrations are expected to decline, though the slow turnover of some sinks for carbon dioxide means that enhanced atmospheric concentrations and the corresponding global warming could persist for tens to hundreds of thousands of years. In addition, other changes, such as loss of the Greenland ice cap, could result in changes to the climate system over the next few thousand years that could persist for hundreds of thousands of years.

Whereas the magnitude of changes in precipitation and infiltration at Yucca Mountain in colder climate episodes can potentially be constrained by reference both to climate modeling studies and climatic reconstructions based on palaeoenvironmental data, future changes in climate and infiltration in an anthropogenically modified warm climate can only be estimated by climate modeling. If the nature of such climate changes was necessarily towards increased aridity, then it could be argued that performance of the system would be improved. However, this is not the case. Global warming is associated with increased evaporation and a strengthening of the hydrological cycle, with delivery of increased energy and moisture to the atmosphere. In these circumstances, substantial reorganization of atmospheric systems can occur and these have the potential to increase precipitation at the site. In particular, there could be an increase in the number and intensity of storm events.

On this argument, the inclusion of anthropogenic climate forcing would result in increased uncertainty in estimates of precipitation and infiltration in the next 10,000 years. Beyond that time, the anthropogenic effect would be expected to weaken slowly. If peak doses were assessed to occur on a 100,000 year timescale, the anthopogenic disturbance on climate and hence the associated uncertainty would either be similar to that in the first 10,000 years or somewhat reduced.

Unsaturated zone flow through Yucca Mountain above the drifts would be largely governed by the present day lithology. As the system is reasonably taken to be geologically stable on a one million year timescale, there is no reason why flow in this zone for prescribed infiltration conditions should be more uncertain beyond 10,000 years than it is before 10,000 years.

On reaching the vicinity of the drifts, uncertainties arise as to the degree to which the infiltrating water enters the drifts and is available for corrosion of the drip shields and waste packages. These uncertainties arise from the spatial heterogeneity of the host rock and the effects of drift excavation, which induces mechanical disturbance and stress redistribution in the host rock, creating a zone with altered formation properties (S Cohen & Associates, 2005, page 2-13). The excavation effects will occur at the beginning of the 10,000 year period. Furthermore, in the first few hundred years, the high temperature of the repository will modify inward flows and the distribution of water in the host rock and may also alter fracture apertures through dissolution and precipitation of minerals. However, these transient changes will die away well within the 10,000 year period. Thus, overall the uncertainties relating to infiltration are mainly either pre-existing, due to excavation of the repository, or are associated with the transient high temperature phase. New sources of uncertainty at long timescales would be limited. One possibility is seismically induced changes to fracture aperture, but as the system is considered to be geologically stable, this should be of limited concern.

Once radionuclides have been leached from the waste packages, they will be transported through the underlying unsaturated zone to the water table. As S Cohen & Associates (2005, page 2-11 and 2-12) has commented, sensitivity studies with the TSPA-SR three-dimensional unsaturated zone flow and transport model showed that 'insignificant changes in transport behavior are found for large changes in fracture aperture…Breakthrough is found to be at most only about 1 order of magnitude earlier than for the base case…for an extremely conservative 10-fold increase in fracture aperture applied over the entire unsaturated zone domain.'

Given the above observation and the geological stability of the system, there is no reason to consider that uncertainties in flow and transport through the unsaturated zone would be significantly increased by seismic effects beyond 10,000 years.

S Cohen & Associates (2005, page 3-13) draw a somewhat different conclusion. They comment that 'as the shields and packages begin to fail, the integrity of the natural barrier system will begin to play a larger role in the overall performance of the repository. Under these conditions, the results may be more sensitive to changes in rock properties caused by seismic activity.' However, this comment neglects the consideration that, as the waste packages begin to fail, uncertainties in the performance of the engineered system decrease, as there is increased confidence in the source term. As seismically induced changes in fracture aperture are not certain to occur and are likely to have only limited effects on flow and transport, it seems likely that the effects of decreasing uncertainties in the source term will dominate.

In respect of near-field chemistry, S Cohen & Associates (2005, page 4-2) have commented that the 'major changes to water and gas compositions that would affect the performance of the geologic system can be represented by fairly coarse periods of constant compositions that have step changes between them. These time periods correspond to the preclosure period, a boiling period, a transitional cooldown period and the extended cooldown period.' However, all these periods are over relatively quickly and in the SSPA, S Cohen & Associates (2005, page 4-5) report that for the ambient period (post-100,000 years), the chemical composition results were based on averages from 2,000 to 100,000 years. Thus, no strong distinctions in near-field chemistry due to thermal effects were identified beyond 2,000 years. S Cohen & Associates (2005, page 4-9) noted the result from the SSPA that 'the long-term composition of fluids around the drift appeared to be controlled primarily by the initial composition of the infiltrating water.' For the TSPA-LA, S Cohen & Associates (2005, page 4-9) commented that 'the initial water compositions and infiltration scenarios are most likely to vary over long time periods.' However, as pointed out above, taking anthropogenically induced climate change into account, variations in infiltration are most uncertain in the period before 10,000 years. Variations in initial water composition are likely also to be correlated with climate change and the degree of infiltration.

In respect to integrity of the waste packages, the main consideration is whether Alloy 22 will behave as anticipated. Here the issue is not primarily about a difference in potential performance before and after 10,000 years, but about performance at any time beyond the periods of a few years over which tests on this material have been conducted. As S Cohen & Associates (2005, page 5-15) comment 'uncertainty also exists in the pessimistic direction. The failure, to date, to identify clear natural or archeological analogs for long term passive metallic behavior seriously limits confidence regarding the stability of passive films in providing extremely long term corrosion resistance.' S Cohen & Associates (2005, page 5-16) further conclude that 'as time progresses, the extrapolation of present knowledge on the decrease of general corrosion rate or establishment of a slow steady state in the optimistic scenarios becomes increasingly less reliable. Likewise, many of the pessimistic scenario processes could require long periods to incubate and their strength and consequences would be increasingly uncertain as time progresses.' These comments are undoubtedly true, but they can be read either as resulting in increased uncertainty with time or as implying decreasing confidence that the waste package will perform as designed and hence the need to place increased weight on assessment calculations in which there have been multiple failures of waste packages. In any event, the decreasing confidence in waste package performance relates to timescales of beyond a few decades. Thus, for example, in the context of localized corrosion, S Cohen & Associates (2005, page 5-17) comment that 'open circuit potential evolution information on Alloy 22 is limited to only a few years and analysis of the responsible factors is only beginning to be studied in some detail…at higher temperatures. As a result, the likelihood of unexpected modes of WP [waste package] corrosion deterioration developing during or around the heat pulse is an important source of uncertainty over shorter time periods.'

As to waste form corrosion, similar considerations apply. That is to say, confidence in the integrity of both the waste package and waste form decrease with time. Thus, uncertainty is initially small, as radionuclides are considered to be isolated from the groundwater environment, increases as waste packages and waste forms fail, and then decreases again when a substantial part of the waste has become accessible. What is at issue is the timescale over which this process occurs. If, it takes hundreds of thousands of years or longer, then uncertainties will still be increasing toward the end of the assumed period of geological stability. Conversely, if it is completed on a timescale of a few thousand years then uncertainties will not increase beyond 10,000 years. There is no general argument that uncertainties in the performance of the engineered barriers must increase beyond 10,000 years. Rather this is a matter to be determined through experiment, modeling and safety assessment.

Following release of radionuclides from the waste, consideration has to be given to their transport in groundwater to the point of abstraction. In terms of water flow, downward percolation from the drifts to the water table is likely to be relatively rapid and determined mainly by variations in infiltration, which is associated with larger uncertainties in the first 10,000 years, because of anthropogenic effects, than beyond that time. As noted by S Cohen & Associates (2005, page 8-1), 'transport time through the SZ [saturated zone] for dissolved, nonsorbing, nonreactive radionuclides can be less than 100 years'. As the DOE considers that the water table is 'now at a low point in the 150,000-300,000 years climate cycle' (S Cohen & Associates, 2005, page 8-16), it seems more likely that transit times will decrease in future rather than increase. Such decreases could occur in the next 10,000 years in the event of increased infiltration.

However, the main uncertainties in transport in the unsaturated and saturated zones are related to the degree of sorption of radionuclides to solids, the extent of diffusion into the rock matrix and the degree of binding to, and transport with, colloids. These uncertainties relate primarily to limitations in data and process understanding that are equally applicable before and after 10,000 years.

Finally, there are uncertainties relating to the biosphere. However, in the context of Yucca Mountain, groundwater abstraction rates are prescribed and the characteristics of the RMEI are to be based on present day characteristics of residents of Amargosa Valley. Thus, there are no distinctions in uncertainty before and after 10,000 years.

In summary, performance assessment calculations undertaken by DOE to date do not provide any evidence for substantial increases in uncertainties beyond 10,000 years and no increases in to degree of caution in assessments beyond 10,000 years have been identified. Indeed, in some contexts, caution can be said to be reduced. For example, the model used for waste-package degradation assumes an idealized geometry (dripping onto the center of the upper surface) that will tend to enhance corrosion rates (other factors being held constant). In the short term this is cautious, as it overestimates the degree of corrosive penetration. However, in the long-term, corrosive penetration of a substantial number of packages would occur both in this geometry and in less ideal geometries, so the degree of caution is reduced. Also, a review of the uncertainties that need to be taken into account in assessments showed that there are some, such as those that relate to infiltration that can be argued to be larger in the next 10,000 years than beyond that time. It is concluded that the variation in uncertainty with time is a matter to be determined by assessment modeling and that it cannot be determined *a priori* to increase with time. In view of this conclusion, it seems inappropriate to base a change in the rigor of the standard of protection on the assumption that uncertainty increases with time beyond 10,000 years.

Conclusions

Overall, the following conclusions are drawn.

- Use of the median rather than the arithmetic mean dose beyond 10,000 years as a compliance measure has no significant advantages and several substantial drawbacks. The median does not necessarily converge more readily than the arithmetic mean, does not give appropriate weight to high dose realizations and is not directly linked to health detriment.
- It is appropriate for DOE and other interested parties to examine the results from assessment calculations to determine whether the individual realizations and the overall sets of realizations are appropriate for use for compliance purposes. Such an examination might result in the exclusion of individual realizations or the requirement to rerun the calculations with modified models or altered sampling of the input parameter values, e.g. to reflect accurately any dependencies between the various parameters. However, once this iterative evaluation of the quality of the assessment has been completed, there should be no reason to give preference to one realization over another in the final evaluation of compliance.
- High dose outliers are such potentially important indicators of performance. It is important to emphasize that the safety of the proposed Yucca Mountain facility needs to be evaluated against the full range of assessment results obtained and not just against some central tendency in those results, irrespective of how that central tendency is defined.
- Performance assessment calculations undertaken by DOE to date do not provide any evidence for substantial increases in uncertainties beyond 10,000 years and no increases in to degree of caution in assessments beyond 10,000 years have been identified. Indeed, in some contexts, caution can be said to be reduced.

- The variation in uncertainty with time is a matter to be determined by assessment modeling and that it cannot be determined *a priori* to increase with time. In view of this conclusion, it seems inappropriate to base a change in the rigor of the standard of protection on the assumption that uncertainty increases with time beyond 10,000 years.

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Mike Thorne and Associates Limited

Michael Thorne

Qualifications PhD FSRP
Year of birth 1950
Nationality British

KEY SKILLS

- Radiological protection
- Assessing the radiological safety of disposal of radioactive wastes
- Distribution and transport of radionuclides in the environment
- Expert elicitation procedures
- Probabilistic safety studies
- Development of safety criteria
- Pharmacodynamics

CAREER HISTORY

2001- **Mike Thorne and Associates Limited**

Development of Models for Radionuclide Transfers to Sewage Sludge and for Evaluating the Radiological Impact of Sludge applied to Agricultural Land
Client – Food Standards Agency

Includes a review of literature and the development and implementation of probabilistic models for such transfers.

Development of Biokinetic Models for radionuclides in Animals
Client – Serco Assurance

Development of updated biokinetic models for use by the Food Standards Agency in their SPADE and PRISM modelling systems

Review Studies for the Proposed Australian National Radioactive Waste Repository
Client – RWE NUKEM

Reviews of reports on animal transfer factors and of the potential effects of climate change on the repository plus development of a model for the biokinetics of the ^{226}Ra decay chain in grazing animals.

Development and Application of a Model for Assessing the Radiological Impacts of ^{3}H and ^{14}C in Sewage Sludge
Client – NNC Ltd

Development of a model based on physical, chemical and biochemical principles for the uptake of 3H and 14C into sewage sludge and their subsequent distribution and transport after application of the sludge to agricultural land.

Support for development of the Drigg Post-closure Radiological Safety Assessment
Client - BNFL

Support in the areas of FEP analysis, biosphere characterisation, human intrusion assessment and the effects of natural disruptive events. In addition, provision of advice of future research initiatives that should be pursued by BNFL.

Co-ordination of biosphere research and participation in BIOCLIM
Client – UK Nirex Ltd

Co-ordination of research on climate change, ice-sheet development, near-surface hydrology and radionuclide transport, as well as participation in an international programme on the implications of climate change for radioactive waste disposal.

Review of Parameter Values
Client – AEA Technology/Serco Assurance

Review of biosphere parameter values for use in the ANDRA assessment model AQUABIOS.

Effects of Radiation on Organisms Other Than Man
Client – AEA Technology/Serco Assurance

Study for ANDRA to identify appropriate indicator organisms and develop appropriate dosimetry and effects models for those organisms.

Development of a Database related to Emergency Planning
Client – AEA Technology (Rail)

Identification of relevant international, overseas and national legislation, regulations and guidance, and production of brief summaries of the documents.

Dose Reconstruction for Workers on a Uranium Plant
Client - McMurry and Talbot

Dose reconstruction for the plaintiffs in a case relating to the Paducah Gaseous Diffusion Plant.

Dose Reconstruction for a Worker Exposed to Pu and Am
Client – Pattinson and Brewer

Dose reconstruction for a worker exposed by a puncture wound in the finger while working at a glove box.

1998-2001 **AEA Technology**

Assessment of Remediation Options for Uranium Liabilities in Eastern Europe
Client - European Commission

Studies of remediation requirements relating to mines, waste heaps and hydrometallurgical plant in Bulgaria, Slovakia and Albania.

Evaluation of Unusual Pathways for Radionuclide Transport from Nuclear Installations
Client – Environment Agency

Review of literature and conduct of formal elicitation meetings to determine potential pathways and evaluate their radiological significance.

Revision of Exemption Orders Made Under the Radioactive Substances Act
Client – DETR

Review of requirements for revision and preparation of a draft text for the purposes of consultation.

Support Studies on the Drigg Post-closure Performance Assessment
Client - BNFL

Support in the areas of FEP analysis, biosphere characterisation, human intrusion assessment and the effects of natural disruptive events. In addition, provision of advice of future research initiatives that should be pursued by BNFL.

Development of Models for the Biokinetics of H-3, C-14 and S-35 in Farm Animals
Client - FSA

Review of relevant literature, development of appropriate biokinetic models and implementation in stand-alone software.

Integration of Aerial and Ground-based Monitoring in the Event of a Nuclear Accident
Client - FSA

Desk-based review and simulation study designed to determine optimum monitoring strategies for different types of accidents.

Elicitation of Parameter Values for use in Radiological Impact Assessment Models
Client - FSA

Expert elicitation study to provide distributions of parameter values for use in the suite of assessment models currently used by the FSA for routine and accidental releases.

Biosphere Research Co-ordination and Assessment Studies
Client - United Kingdom Nirex Ltd

Continuation of a programme of work originally undertaken at Electrowatt Engineering (UK) Ltd

Site Investigation and Risk Assessment - Hilsea Lines
Client - Portsmouth City Council

Radiological assessment of a radium-contaminated site.

1987-1998 **Electrowatt Engineering (UK) Ltd**

Evaluation of Inhalation Doses from Uranium
Client - Baron & Budd

Provision of expert witness support in a class action relating to environmental exposure from a uranium plant.

Biosphere Studies Relating to Drigg
Client - BNFL

Provision of advice on time-dependent biosphere modelling for the Drigg low-level radioactive waste disposal facility.

Development of a Siting Policy for Nuclear Installations: Harbinger Project and Follow-up Study
Client - HSE/NSD

Review of existing policy and development of alternatives as a precursor to application to a wide range of installations, not restricted to commercial reactors.

Support to the Rock Characterisation Facility Public Enquiry
Client - UK Nirex Ltd

Preparation of position papers and rebuttals of evidence.

Radiation Doses to an Individual as a Consequence of Working on the San Onofre Nuclear Power Plant
Client - Howarth & Smith

Interpretation of personal and area monitoring data for legal purposes.

Interpretation of Uranium in Urine Data for the Fernald, Ohio Feed Materials Processing Center
Client - Institute for Energy and Environmental Research

Interpretation of urinalysis and lung counting data, and appearance as an expert witness in the associated trial.

Determination of Failure Probabilities for use in PRA
Client - Nuclear Installations Inspectorate

Development of new approaches to the use of Bayes Theorem in defining component failure probabilities for use in PRA when statistics on actual failures are limited.

Review of Inventory Information
Client - UK Nirex Ltd

Review of uncertainties in inventories of individual radionuclides.

ALARP Study of Options for the Treatment, Packaging, Transport and Disposal of Plutonium Contaminated Material
Client - UK Nirex Ltd

Use of multi-attribute utility analysis to establish which option is preferred.

Expert Judgement Estimation of Intrusion Model Parameters
Client - British Nuclear Fuels plc

Project Manager of a study assessing the risks of human intrusion into Drigg radioactive disposal site using expert judgement techniques.

Brainstorming Study of Risks Associated with Building Structures
Client - Building Research Establishment

Participation in a classification study of the health risks associated with buildings including both injuries and disease.

Rongelap Resettlement Project
Client - Marshall Islands Government

Participation in an oversight committee evaluating the radiological safety of Rongelap in the context of resettlement by its evacuated community.

Radiological Consequences of Deferred Decommissioning of Hunterston A
Client - Scottish Nuclear Ltd

Project Manager of a study of the radiological impacts of groundwater transport of radionuclides, releases to atmosphere and intrusion.

Reviews of Safety Documentation
Client - UK Nirex Ltd

Review of safety related documentation for Packaging and Transport Branch.

The Sheltering Effectiveness of Buildings in Hong Kong
Client - Ove Arup & Partners

Project Manager of a study evaluating the shielding effectiveness of all types of building in Hong Kong for volume sources of photons in air and surface deposition sources.

Assessment of the Radiological Impact of Releases of Radionuclides from Premises other than Licensed Nuclear Sites
Client - Ministry of Agriculture, Fisheries and Food

Project Manager of a study to identify representative premises, obtain data on their releases of radionuclides and assess radiological impacts using a new methodology developed for the project.

Assessment of the Radiological Implications of Uranium and its Radioactive Daughters in Foodstuffs
Client - Ministry of Agriculture, Fisheries and Food

Project Manager of a review study of concentrations of uranium and its daughters in foodstuffs, taking local and regional variations in uranium concentrations in soils, sediments and waters into account.

Radionuclides in Sewage
Client - Her Majesty's Inspectorate of Pollution

Project Manager of a study including a desk review on alternative methods of disposal of sewage sludges, interpretation of monitoring data relating to radionuclide discharges from Amersham International to the public sewer system, development of a model for radionuclide transport in sewers, and collection and analysis of effluent, foul water, sediment, sludge and other samples suitable for use in model validation studies.

Accident Consequence Calculations
Client - Nuclear Installations Inspectorate

Project Manager of a study to assess the radiological consequences of various atmospheric releases using the MARC code.

Definition of Threshold Recording Levels for Drums of ILW
Client - UK Nirex Ltd

Project Manager of a study of the implications of post-closure radiological impacts of radioactive waste disposal in defining Threshold Recording Levels for radionuclides in individual waste drums.

Definition of Expert Judgment Exercises Relating to Nuclear Safety
Client - Commission of the European Communities

Project Manager for a study defining expert judgment exercises relating to conceptualisation, representation and input data specification. Included a comprehensive review of available formal expert judgment procedures, and mathematical and behavioural aggregation techniques.

Definition of Research Requirements Relating to the Use of Expert Judgment in Parameter Value Elicitation for Reactor Safety Studies in a UK Context
Client - Nuclear Safety Research Management Unit, HSE

Development of proposals for using combined behavioural and mathematical aggregation procedures in formal elicitations of expert judgment.

Development Priorities for the Drigg Technical Development Programme
Client - British Nuclear Fuels plc

Provision of detailed advice to BNFL on future design options, and research and development priorities, in relation to radioactive waste disposal at Drigg.

Channel Tunnel Safety Studies
Client - Channel Tunnel Safety Authority

Provision of advice and guidance on safety criteria appropriate to the Fixed Link, on the classes of Dangerous Goods that may properly be carried and on the overall characteristics of the proposed Safety Case.

Development of Societal Risk Criteria
Client - Marathon Oil

Interpretation of F-N curves in the context of the offshore oil/gas industry, taking risk aversion into account.

Impacts of Salt Dispersal on Plant Communities
Client - Sir William Halcrow

Evaluation of salt dispersal from a major road in winter in relation to adjacent Sites of Special Scientific Interest.

Offsite Consequence Assessments
Client - Nuclear Electric

Studies of the offsite radiological impacts of atmospheric and liquid releases of radioactive materials from Magnox stations.

Dry Run 3
Client - Her Majesty's Inspectorate of Pollution

Uncertainty and bias studies involving formal expert judgment procedures to develop a conceptual model of those factors and interrelationships which are of significance in determining the post-closure radiological impact of a deep geological repository for radioactive wastes. This project also included advice on data and models to be used for post-closure radiological assessments.

Radiological Assessments of Drigg
Client - British Nuclear Fuels plc

Project Manager for post-closure radiological impact assessments of the Drigg LLW disposal site. Also included specification and development of computer codes relating to the radiological impact of fires, releases of radioactive gases produced by microbial action and metal corrosion, and human intrusion.

Biosphere Co-ordination
Client - UK Nirex Ltd

Co-ordination of the UK Nirex Ltd Biosphere Research Programme from its inception, including requirements definition, technical management of all projects and QA surveillance as the Client's Representative.

Biosphere Support for the Nirex Disposal Safety Assessment Team
Client - AEA Technology

Development of approaches for assessing the radiological impact of releases of radionuclides to the biosphere, plus advice on radiological protection criteria, definition of individual risk, implications of conventionally toxic chemicals in wastes and a variety of other matters.

Evaluation and Radiological Assessment of Liquid Effluent Releases from Various Premises
Client - Her Majesty's Inspectorate of Pollution

Reviews of monitoring data and evaluations of radiological impact, primarily related to Harwell, Aldermaston, Capenhurst and Amersham International.

Evaluation of the Radiological Impact of Overseas Nuclear Accidents
Client - Her Majesty's Inspectorate of Pollution

Studies of the impact of potential overseas nuclear accidents on the UK, with emphasis on survey and monitoring requirements, and the selection of appropriate radiation detection equipment for monitoring.

Bilsthorpe Power Station
Client - British Coal/East Midlands Electricity

Preparation of an Environmental Statement with emphasis on atmospheric dispersion of SO_2 and NO_x.

Gas Generation in Radioactive Waste Disposal Facilities
Client - AEA Technology

Development of a coupled microbial degradation and corrosion model for gas generation in repositories for LLW and ILW.

Effects of Chernobyl on Drinking Water Supplies
Client - Her Majesty's Inspectorate of Pollution

Evaluation of the radiological implications of enhanced concentrations of radionuclides in water supplies in England and Wales subsequent to the Chernobyl accident.

Sea Disposal of Radioactive Wastes
Client - UK Nirex Ltd

Participation in an Environmental Impact Assessment of the proposed resumption of sea-dumping of radioactive wastes.

UK Research Related to Radioactive Waste Management
Client - Her Majesty's Inspectorate of Pollution

Identification of gaps in the UK national research effort related to radioactive waste management.

Research Requirements for Repository Design and Site Investigations
Client - UK Nirex Ltd

Review of research requirements for repository design and site investigations in relation to LLW and ILW disposal in near-surface and deep repositories.

1985 - 1986 **International Commission on Radiological Protection, Sutton, Surrey, England**

Scientific Secretary responsible for arranging and minuting meetings, administrative arrangements, technical review of reports, editing of the Commission's journal, liaison with other international organisations and public relations.

1979 - 1985 **ANS Consultants Ltd, Epsom, Surrey, England**

Reviews of data on the distribution at transport of radionuclides in terrestrial and aquatic ecosystems (see publications list).

Development of a dynamic model for radionuclide transport in agricultural ecosystems and implementation of the model on various microcomputer systems.

Photon and neutron shielding studies of radiochemical plant, together with area classification and ALARA studies.

A review of UK use of the criticality code MONK and other approaches to criticality safety assessment.

Radiological and conventional safety aspects of Magnox reactor decommissioning.

Development of metabolic models for inclusion in ICRP Publication 30.

Development of pharmacodynamic models for toxic chemicals.

Review of neutron activation analysis in studies of radionuclide transport in soils and plants.

Experimental studies on radionuclide transport in soils and plants using various photon-emitting radionuclides.

Support for DoE work on probabilistic risk assessment of LLW and ILW disposal.

Review of UK research requirements for HLW disposal.

Post-closure radiological impact assessment of the proposed LLW and ILW facility at Elstow, Bedfordshire.

Development of a generalised biosphere model for use in probabilistic risk assessments of solid radioactive waste disposal.

Initial development of a mathematical model for use in assessing the radiological impact of contaminated groundwater.

Development, computer implementation and comprehensive documentation of a model to calculate the radiological impact of intrusion into radioactive waste repositories.

Development of a general-purpose computer code for solving first-order differential equations using a hybrid Predictor-Corrector/Runge-Kutta method.

Studies on the potential radiological consequences of Magnox reactor accidents.

1974 - 1979 **Medical Research Council Radiobiology Unit, Chilton, Didcot, Oxon, England**

Development of dosimetric and metabolic models for use in ICRP Publication 30.

Studies on the metabolism of plutonium in bone and relationships to blood flow.

Theoretical studies on radionuclide metabolism and dosimetry.

Development of techniques in neutron-induced autoradiography and alpha imaging.

Image analysis studies of plutonium in bone, uranium in lungs, lysosomal inclusions in cells and heterochromatin.

Studies on the clearance of inhaled UO_2.

Alpha spectroscopy in support of toxicity studies with Ra-224.

Data analysis in connection with experimental animal studies on the potential efficacy of neutron therapy using 42 MeV neutrons.

1971 - 1974 **University of Sheffield**

Experimental studies on the reaction $\gamma + p \rightarrow \pi^0 + p$ at photon energies between 1 and 3 GeV, using a linearly polarised photon beam.

PROFESSIONAL ACTIVITIES AND MEMBERSHIP

- Fellow of the Society for Radiological Protection and Immediate Past President
- Member of the Eco-ethics International Union
- Visiting Fellow at the Climatic Research Unit, University of East Anglia

SELECTION OF PUBLICATIONS

A measurement of the beam asymmetry parameter for neutral pion photoproduction in the energy range 1.2 - 2.8 GeV. P.J.Bussey, C. Raine, J.G. Rutherglen, P.S.L. Booth, L. Carroll, G.R. Court, A.W. Edwards, R. Gamet, C.J. Hardwick, P.J. Hayman, J.R. Holt, J.N. Jackson, J. Norem, W.H. Range, F.H. Combley, W. Galbraith, V.H. Rajaratnam, C. Sutton and M.C. Thorne. London Conference (1974) Abstract 997.

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The polarised beam asymmetry in photoproduction of eta mesons from protons 2.5 GeV and 3.0 GeV. P.J. Bussey, C. Raine, J.G. Rutherglen, P.S.L. Booth, L.J. Carroll, P.R. Daniel, A.W. Edwards, C.J. Hardwick, J.R. Holt, J.N. Jackson, J. Norem, W.H. Range, W. Galbraith, V.H. Rajaratnam, C. Sutton, M.C. Thorne and P. Waller. Physics Letters, 61B, (1976) 479-482.

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The distribution and clearance of inhaled uranium dioxide particles in the repository tract of the rat. Donna J. Gore and M.C. Thorne. In "Inhaled particles IV", Ed. W.H. Walton, (Pergamon Press, Oxford, 1977) pp. 275-284.

Theoretical aspects of the distribution and retention of radionuclides in biological systems. M.C. Thorne. J. Theor. Biol., 65, (1977) 743-754.

Aspects of the dosimetry of emitting radionuclides in bone with particular emphasis on Ra-226 and Pu-239. M.C. Thorne. Phys. Med. Biol., 22, (1977) 36-46.

A new method for the accurate localisation of Pu-239 in bone. D. Green, G. Howells and M.C. Thorne. Phys. Med. Biol., 22, (1977) 284-297.

The measurement of blood flow in mouse femur and its correlation with Pu-239 deposition. E.R. Humphreys, G. Fisher and M.C. Thorne. Calcif. Tiss. Res., 23, (1977) 141-145.

The distribution of plutonium-239 in the skeleton of the mouse. D. Green, G.R. Howells, M.C. Thorne and J. Vennart. In "Proceedings of the IVth International Congress of the International Radiation Protection Association Vol. 2 (Paris 1977).

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Lymphoid tumours and leukaemia induced in mice by bone-seeking radionuclides. J.F. Loutit and T.E.F. Carr with an appendix by M.C. Thorne. Int. J. Radiat. Biol., 33, (1978) 245-263.

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Appendix D

White Paper
Intergenerational Equity as it applies to 40 C.F.R. Part 197

Patricia Ann Fleming, Ph.D.

My charge as an Independent Consulting Expert for the State of Nevada:

I have been asked by the State of Nevada to write a white paper on the ethical issues which present themselves in the August 22, 2005 EPA proposal for radiation protection standards at Yucca Mountain. In particular, I have been asked to comment on intergenerational equity as it applies to these standards. I confine myself to this task and introduce other issues in 40 C.F.R. Part 197 which are related to this task.

Format of my response to my charge:

I have some familiarity with the processes by which an entity (federal agency, national committee, etc.) elicits responses during a comment period to the concerns it has undertaken. Hence, I have chosen the style below of posing questions/statements and providing comments (rather than the more didactic style familiar in my own profession of philosophical scholarship) on the issues relevant to my task at hand. My objective is to ease the task of understanding what I take to be the most significant issues regarding intergenerational equity (and associated topics) raised by 40 C.F.R. Part 197.

1. What is *ethically significant* about EPA issuance of a new guidance at 40 C.F.R. Part 197?

The NAS Committee on Technical Bases for Yucca Mountain Standards of the National Academy of Sciences rejected two technical reasons commonly given for not providing guidance beyond 10,000 years--that uncertainty exists in compliance assessment and that there is a likelihood of no significant health effects after a specified time. However, they point out that a time-related regulatory concern remains. "This is based on ethical principles, and is the issue of intergenerational equity." (NAS 1995, p. 56) They say

> *Whether and how best to be fair to future generations is a societal concern...In drafting standards, EPA should as a matter of policy address whether future generations should have* ***less, greater, or equivalent protection.*** *" (NAS, 1995, p.56, emphasis added).*

EPA is making an ethically significant judgment about the issue intergenerational equity, i.e. fair and just treatment toward future generations in their proposed rule at 40 C.F.R. Part 197.

2. Did the EPA ignore the NAS Committee's recommendation on the matter of intergenerational equity?

In its Tech*nical Basis for Yucca Mountain* report, the National Academy of Science committee cites responsible institutions on the question of the protection standard. They remind us of a societal pledge to future generations made by Margaret Federline, USNRC to "provide societies with the same protection from radiation we would expect ourselves" (NAS, 1995, p.56) and an international document from IAEA which asserts that " the degree of isolation of high-level radioactive waste shall be such so there are no predictable future risks to human health or effects on the environment that would not be acceptable today" (NAS, 1995, p. 56) and that "the level of protection to be afforded to future individuals should not be less than that provided today." (NAS, 1995, p. 56) The committee notes that such a standard "could be specified to apply uniformly over time and generation. Such an approach would be consistent with the principle of intergenerational equity that requires that the risks to future generations be no greater than the risks that would be accepted today." (NAS, 1995, p 57). The Committee also cites the following reason that is often given by ethicists in support of a greater level of protection in order to compensate for risks imposed on non-consenting populations:

> *Although current generations are assumed to have benefited from activities, such as electricity production or national defense programs that have caused radioactive wastes to accumulate, far future generations will not benefit directly, but might be exposed to risks when any radioactive materials eventually escape the proposed repository (NAS, 1995, p.56).*

Based on these comments, one might conclude that the NAS committee favors an equivalent or even a greater protection standard for individuals living beyond 10,000 year to peak dose and that EPA, in its proposed rule, ignored the committee's guidance. The committee is clear, however, that how the principle of intergenerational equity is best expressed is a matter of social, not scientific, judgment. As a scientific body, the NAS Committee did not (and would not) explicitly recommend an equivalent or greater protection standard. Committees will lean heavily in one direction on social judgment issues and this august body seems to have leaned *away* from a lesser protection standard for future generations. Nothing that it says in their report supports less protection. Nevertheless, they were clear in articulating that the burden falls to the EPA to ascertain the judgment of society regarding an acceptable expression of the principle of intergenerational equity.

3. How does EPA ascertain the judgment of society regarding an acceptable expression of the principle of intergenerational equity?

Unlike other countries (e.g. Sweden), the United States does not have national referendums. Moreover, EPA is not proposing legislation to specify a societal judgment. This is why the comment period for 40 C.F.R. 197 is so important. It is the mechanism EPA uses to hear the judgments of individual members of society as well as stakeholder groups. In fact, the NAS committee says, "The rulemaking process, directly involving public comment to which an agency must respond, is an appropriate method of addressing the questions of an appropriate level of protection." (NAS, p.49). After the comment period ends, in its response, the EPA assumes the extremely important ethical duty of deciding what is the socially acceptable expression of the principle of intergenerational equity.

4. Does the EPA conceive of future generations as NAS describes them in their 1995 report?

No. NAS did not make a distinction between near future and far future generations. NAS accepted the common distinction found in the scholarship on intergenerational equity, i.e. a distinction between present generations and all future generations taken together. The distinction drawn by EPA is between 1) present and near future generations up to 10, 000 and 2) far future generations from 10,000 years to 1 million years, regardless of when peak dose occurs. EPA cites references from the nuclear waste community which establish several distinctions (but different than its own) among future generations. EPA's distinction seems to be a vestige of the standard rejected by the Court of Appeals.

5. What does EPA say about the present generation's duty toward future generations?

In 40 C.F.R. 197, EPA effectively claims that present generations are entitled and duty-bound to hold near future generations in the same regard but far future generations in less regard than present generations This is expressed in the recommendation that it is permissible to provide far future generations with less protection than present and near future generations.

6. Where does the EPA advance the ethical claim that less protection is required for the far future (from 10,001 to peak dose)?

The first place in EPA's Proposed Rules where the subject of providing less protection to far future generations *as an ethical claim* is discussed is in on page 49035 (Vol. 70, No 161). EPA says, "We have also considered the potential impacts to future generations that would be represented by a dose standard applied to periods up to 1 million years. Impacts on future generations could come in the form of economic cost, health impacts or a reduction in the options available to make decisions to address the problems faced by those generations. A number of regulatory and scientific bodies suggest that it is appropriate to relate longer-term standards to background radiation levels." This is the first indication (other than in the summary section) that the EPA regards it socially acceptable to provide less protection to far future generations by raising the dose standard from 15mrem/a to a higher level (i.e. something *related to* background radiation levels—350mrem/a).

7. How does the EPA support what they say?

They provide underlying ethical arguments, drawn primarily from scholarship by individuals either funded by DOE (NAPA) or involved internationally in regulatory bodies (NAGRA, KASAM). This scholarship focuses on the claim that we might have weaker obligations to future generations than to present persons and near-term generations.

For example, the EPA cites a National Academy of Public Administration (NAPA) 1997 report "Deciding for the Future: Balancing Risks, Costs, and Benefits Fairly Across Generations." They point out that NAPA "recognizes that each generation must consider not only how its actions will affect future generations, but also the extent to which inaction will compromise its own interests and negatively affect those same generations." (EPA, p. 49035)

After listing four basic principles from the NAPA document (three of which some version is generally recognized among environmental ethics scholars as relevant to environmental concerns) and by appealing to the concept of a "rolling present", the EPA concludes that application of these principles would "lead each generation to an approach that would best address the problem without unduly limiting the options available to succeeding generations to modify that approach or to take other actions to address their needs."

This scholarship is a valiant attempt to make sense of a difficult and thorny issue facing nations with nuclear waste sitting in cooling ponds at reactor sites. The authors of these studies or the agency contracting for the study are all involved with this concern (McCombie-Switzerland, Chapman-UK, KASAM-Sweden, NAPA-U.S. DOE).

8. Are there problems with this support?

Although they provide background documents of the an annotated bibliography of scholarship on intergenerational equity from 1992 backwards, the conclusions NAPA draws has not been vetted or reviewed among the *larger* community of scholars working on intergenerational equity. This is evidenced by the fact, despite the report being in existence for the last 13 years, major scholarship in this field today does not cite the NAPA sources. The sources used by EPA tend, instead, to cite each other. Consequently, the scholarship lacks balance, contains logical errors, (McCombie and Chapman), and, in some instances, is a misapplication to cases (NAPA, EPA, KASAM). It almost appears as if the EPA searched for and found scholarship which exclusively supports (or they interpret to support) the "less protection" expression of intergenerational equity, rather than openly asked what would be the most rationally defensible and socially acceptable protection standard for future generations

9. Is there better support for a different conclusion?

The bulk of scholarship on intergenerational equity is done by professional philosophers/ethicists. Associated scholarship exists in the fields of environmental economics and international law. This scholarship, while it looks far more deeply at the profound issues surrounding the question of our duties to future generations, does not always apply its results to high level nuclear waste disposal. Nevertheless, considerable scholarship exists from this professional community of scholars on the important issue of intergenerational equity facing the EPA and should be taken into account. It has been vetted through peer review and does not commit the errors made by the EPA. This scholarship does not (or would not) support the "less protection" expression of intergenerational equity as it is applied to the standards proposed by EPA

Instead, this scholarship shows either we have no duties to future generations or, if we do, our duties are the same as those to present generations, assuming the duty is to leave the future is no worse shape than the present finds itself. For example, the author of a leading and standard textbook in the field of environmental ethics states, "Future people should have the same opportunity that we have had to live healthy, happy, and satisfactory lives. The basic interests of future people are no more, and no less, importantly ethically than our own." (DesJardins, p. 82).

10. Does it matter that there are different viewpoints in the scholarship on intergenerational equity? Hasn't the EPA acted properly in choosing the sources which best support its position on a controversial issue?

This is not simply a matter of there being controversy in the field; rather, what is disconcerting about the scholarship chosen by the EPA to defend its choice of a "lesser protection standard" for the human health of future generations is that their sources or, more often, their *use* of the sources are:

1) misapplied

2) not rationally defensibility

3) fail to avoid logical and other errors.

11. How has the EPA misapplied their sources?

The EPA has misapplied one of their sources, the NAPA document, in two key ways.

12. What is the first way in which EPA misapplied the NAPA document findings?

First, the NAPA report clearly states that the four principles it elicits from its background studies of literature (from December, 1993 backward) and its workshop in phase two of the project supported by the DOE, are very preliminary. They "represent only the first step toward improving public decision making in a broad range of activities that affects future generations. Obvious next steps are elaborating a set of working guidelines showing how to apply them in specific situations;..." (NAPA, p. 3) Later in Chapter 3 of the report, the NAPA panel develops some initial guidance for applying each principle but warns that much more work remains to be done. They say "In the best of circumstances, with all of the necessary guidance, the application of the principles presented here would be a daunting task." (NAPA, p. 13) They construct a simple matrix that is intended to provide a way to prioritize a public administrator's obligations, or to give him/her a sense of which issues he/she should tackle first (the priority is given to issues presenting risks affecting both the present and future generations.) They add that the matrix is inadequate for addressing complex issues and further work is needed to develop it into a useful decision making tool. They say "For example, the idea of addressing the highest near term risk first will not help in deciding between a certain risk now versus an uncertain risk either now or many generations in the future." (NAPA, p. 13) Throughout their report, this panel stresses that what they have provided is just a start, should not be used "off the shelf", and must include the public in determining risk and evaluating the risk's relative importance.

Related to this first problem of misapplication of the NAPA report is the context in which it is used, i.e. for a comment period in which the public has no more that 60 days (extended to 90 days by petition of the State of Nevada) to respond to their use. Figure 4-1 of the panel's report would require more that 90 days for the principles to be processed (including public participation and public judgment), and for the outcomes to be realized, i.e. 1) public agreement on the principles, 2) public agreement on processes, 3) a politically acceptable decision, and 4) enhanced public trust.

Given all these cautions and caveats, it is clearly inconsistent with the panel's report for EPA to cite the four principles and apply them indirectly through reference and subtle inference. Doing this supports, at best, a vacuous conclusion that, through a "rolling present", each generation should address the problem with an approach that does not unduly limit the succeeding generations to modify that approach. Appealing to the concept of a rolling present in a general discussion document is speculative, idealistic, and perhaps even hopeful. But the Proposed Rules, presented as a response on August 22, 2005 to the Court's earlier July, 2004 decision, is not this kind of document. Hence, the conclusion EPA draws has no real meaning for the provisions of the current Nuclear Waste Policy Act under which the EPA has control. This is because, among other things, taking seriously a "rolling present" would effectively obligate future generations to review the individual protection standards (if not all the standards and the entire Nuclear Waste Policy Act) every 20 years. Nowhere does the EPA make this recommendation. In addition, the EPA cannot rely on any concrete provisions in the Nuclear Waste Policy Act for the *institutional constancy* needed to give real meaning to a "rolling present." Neither do they propose any such provisions. Hence, in using the NAPA report results as it does, the EPA oversimplifies and contradicts what NAPA tried to achieve.

13. What should EPA do to rectify this misapplication?

To be consistent with the NAPA panel report recommendations, the EPA should have "(sought) out and utilize (d) public participation early enough in the process to have a meaningful effect on its outcome." Now, when they are at the end-period of producing individual protection standards for peak dose (and only as a result of the Court's decision), they would need to extend the time period and institute a mechanism other than merely a comment period and reactive hearings to insure that the NAPA's expected outcomes are realized. There are ample models being used today by nations and international groups to effect such outcomes but these models take time, patience, and better communication with stakeholders and the general public (see, for example, the results of the NEA/OECD Stakeholder Conference Workshops). In addition, if we accept EPA's understanding of "the rolling present", EPA would need to seek revision of the Nuclear Waste Policy Act in order to create a process that is "continuous and adopts a rolling present responsibility flowing from one generation to the next without interruption." (NAPA, p. 8). They should also ensure that a revised act provides 1) in general, continued research and education about risks associated with nuclear waste disposal and 2) in particular, regularly reexamined and revised individual protection standards. Since "the rolling present" is meant to *substitute* for geological and biospheric stability in the face of uncertainty, such institutional stability, as its substitute, needs to be guaranteed for future generations. (see No. 20 below for further comments on this point which point out that EPA has misapplied the concept of a "rolling present.").

Without such changes, it is questionable as to whether the concept of a "rolling present" is much more than an idealistic vision of how we might *implement* our duties to future obligations. Alternatively, they should abandon such a simplistic and contradictory appeal to the NAPA panel report. The fact that other entities (KASAM and Chapman and McCombie) also appeal to this report does not alter the fact that the EPA has misapplied the report findings by including it as support for their Proposed Rules. In using the NAPA panel report as they do in their Proposed Rules, EPA runs the risk of "put (ting) themselves in the position of advocating policies or programs that are unrealistic and will not be supported by a reasonable public consensus and acceptance." (NAPA, p. 27) It is necessary to avoid this "because intergenerational obligations must ultimately be borne by our society as a whole and not just by the bureaucratic apparatus of government." (NAPA, p. 27)

14. What is the second way in which EPA has misapplied the NAPA report findings?

The second misapplication of the NAPA report is derived from thinking that NAPA's own self-admittedly "simplified illustration" supports the EPA proposal to provide lesser protection to future generations than the present. This illustration concerns a matter close to but not identical with EPA's task at hand. The NAPA panel illustrated how the principles can be used *as a set* in decision making and priority setting. The issue they apply the set of principles to is "How should risk to populations in the near future (e.g. 2 or 4 generations) be compared to risks to populations in the distant future (e.g. 500 or 1000 years)" which is taken from Appendix A, III. Q1. (NAPA, p. 22).

The panel argues that the Trustee Principle is trumped by the Chain of Obligation Principle because of our limitations in addressing the very long-term. It presumes that a probable difference between the risks to present and future populations cannot be detected and so the risks cannot be compared. Because of this difficulty in comparison of real risks, the Chain of Obligation principle requires us to attend to our duties to present and near-future generations.

The Chain of Obligation Principle also trumps the Sustainability Principle. While the Sustainability Principle "admonishes us not to deprive future generations of a quality of life like ours" (NAPA, p. 12), the Chain of Obligation principle trumps sustainability because it "accommodates a natural tendency to prefer near-term over the long-term" and it acknowledges the uncertainty and low probability of future events. The only sense we get that the Chain of Obligation Principle might not top a hierarchy of principles is in the Precautionary Principle's requirement to limit any preference for the near term if there is any plausible threat of irreversible harm or catastrophic damage.

The example used to illustrate this is an accident in 1957 in Chelyabinsk, Russia where surface storage of radioactive waste blew up, contaminating surrounding areas for hundreds of years. The NAPA panel concluded that in making a decision to continue surface storage of liquid waste rather than solidifying it and disposing it in a geological repository, even if such storage were less expensive, "any plausible threat of such an event occurring in the far future should be given additional weight." (NAPA, p.13)

There are several features about this (truly) simplified illustration that commit errors mentioned in No. 10 above. Below, (a) through (c) describe some internal problems with the NAPA report, which should have encouraged EPA to be cautious about its use. The vetting of this report among the peer-review community of ethicists may have caught these errors. Further below (d) describes a misapplication of the NAPA report by the EPA.

a. NAPA's application of the set of principles in this case is not rationally defensible. The Chain of Obligation Principle would *almost always* trump our trusteeship obligation and any sustainability obligation whenever uncertainty exists. This is because, according to the NAPA panel, uncertainty is a morally relevant characteristic in determining our duties. It can only be trumped by catastrophic harm. This would be strangely precedent-setting. One can always argue uncertainty exists. In almost all areas of environmental concern there will always be uncertainty. Does it have that much power to derail duties we have to persons living in the future? While we might think that uncertainty affects our moral duties, do we really want to say that uncertainty dissolves or reduces moral responsibility? If the NAPA committee did not intend this result, they needed to have stated this clearly.

b. It is illogical and ethically irrelevant as to whether any principle, and in particular the Chain of Obligation Principle, accommodates a natural tendency. This is a statement about our moral psychology at best. It is not a normative claim. It attempts to derive "ought" from "is." Assuming this is a correct, empirically verified statement about our natural moral disposition, nevertheless professional ethicists generally reject attempts to base our moral obligations on our natural tendencies. The consequences of doing so are quite problematic because we know that our natural tendencies are not, by virtue of being natural, necessarily morally praiseworthy. Additionally, economists will be the first to argue that, when engaged in economic planning, we should not follow any "natural inclination" to favor the present. We should be concerned with what is most "rational" (i.e. stands up to scrutiny by rational actors), not what is most "natural."

c. The Precautionary Principle may lead to the claim that our obligations to future generations are **greater** than those to present generations. The example is meant to illustrate this. But, in fact, it is miscast. In the example given, the probability of harm from a nuclear accident potentially endangers both the present as well as the future. To keep liquid waste in an unmonitored state, allowing the loss of cooling, is not defensible under any version of the principles above. It is simply irresponsible to both present persons and the future generations. It is not an apt illustration of a case in which the present is rationally preferred over the future. . At best, if cost was the prime consideration, the example should be characterized as one in which present regulators (in 1957) miscalculated the risks over costs to both present and future generations, not one in which the well-calculated risks to future generations outweighed any well-calculated risks to present persons (on some utilitarian calculus that is assumed to have intentionally occurred in 1957). It's a bad example.

d. Most significantly, if the Chain of Obligation Principle is applied to the issue at hand (as the EPA Proposed Rules infer), then near-term concrete hazards have priority over long-term hypothetical hazards. What is the near-term concrete hazard at issue? EPA does not identify or evaluate it, so it is impossible to comment on EPA's application of the Principle. I will return to this point shortly.

What is the long-term hypothetical hazard? Here, things become more complex. If by this expression, the EPA, Chapman and McCombie, KASAM and others in the nuclear community define 'hypothetical hazard' to mean 'the uncertainty associated with the geological structure or with the way in which a repository will perform in the distant future', then this is a misconstruction of the term. The ethical framework under discussion is designed to evaluate the acceptability of risks, not to specify the limits of uncertainty in doing a performance assessment. The hazard being addressed by the individual protection standard under consideration is the hazard to human health, in the far-future, associated with exposures to 350 mrem . Are these health affects hypothetical? The answer the EPA must give to this question is "No. These health affects are no more hypothetical in the future than they are in the present. Radiation sciences, including radiation epidemiology, provide us with an understanding of the health affects of exposure to radiation. We base our protection standards in part on this work. This knowledge is frozen in time by other parts of the EPA rule (40 C.F.R. 197.15). The EPA presumes that the human living in the far future is similar to the human living in the present and near-future. Without this assumption, the EPA task of establishing individual protection standards would be impossible to accomplish beyond a few generations.

15. If the far-term hazards from radiation exposure to human health are no more hypothetical than those to the present and near-term generations, what other meaning could be given to near-term hazards so that the idea that the Chain of Obligation Principle supports the creation of a multiple dose standard in which far future generations would receive less protection?

It is possible that what the nuclear waste community means by near-term hazard is the hazards to human enterprises if a repository were not licensed, opened, filled, and closed within the next 30 years. In other words, a near-term hazard would be the risks associated with not being able to license and operate a nuclear waste repository in the very near future. But there are multiple problems with such an approach in this rule making. First, it would be a pure guess to say this is the near term hazard EPA has in mind in applying the principle. Second, even assuming it is, EPA offers us no specific estimate of what the magnitude of this hazard might be, let alone any supporting evaluation, on which one could comment. Third, it is certainly not a given in any event that the near term hazards from failure to have a repository in the next thirty years or so would counterbalance the hazards from Yucca, considering that large quantities of spent fuel will be stored on reactor sites for many decades to come even if Yucca is licensed tomorrow, and that the duration of exposures to 350 mrem could be many hundreds of years, a much greater time that thirty years or so. Finally, we cannot assume 350 mrem is necessary to avoid a failure in the repository program unless we assume the program consists only of Yucca mountain and Yucca Mountain will fail if there is a stricter standard. But this would mean the whole EPA rule begs the question of the safety of Yucca.

In any event, the Chain of Obligation Principle used by EPA would not apply in this analysis because we are not comparing hypothetical and non-hypothetical (or concrete) hazards.

16. Since the hazards to future as well as present generations are not hypothetical, how would ethics justify the preference of the present over the future?

What we are being asked to consider is this question: Is it ever fair or just to act differently toward far- future generations than we do toward present and near-future generations?

There are at least two traditions in ethics which provide answers to this question: the egalitarian tradition (related to a deontological approach to right/wrong, wherein some feature of the act itself and not its consequences, determines right and wrong actions or just and unjust policies; and the 2) the consequentialist tradition (related to a utilitarian approach and often reduced to RCBAs, wherein the consequences of the act or policy, such a risks, benefits, and costs, determine right and wrong action or just and unjust policies.

For egalitarians, equity or fairness is a moral concept of right proportionality. Equity does not simply involve treating persons equally, but rather *treating like persons alike. Equity allows us to treat persons differently if there are relevant differences between them, but it enjoins us not to discriminate where there are no such differences.* Hence, equity requires consistency of treatment. We would be charged with discrimination if we had no good moral grounds for doing otherwise. We must look to certain features of the persons or generations in question to determine if those features change the nature or strength of our moral duties.

Future generations are not yet living; they do not exist. Specific persons may never come into existence since our present actions affect the future. We do not know what they will be like. Some ethicists (egalitarians and consequentialists alike) have argued that all these features, i.e. the non- existence of future humans, which specific humans will exist, their DNA structure, and their abilities to withstand disease, affect our obligations to future persons. They, in fact, establish that future persons have NO moral worth. These time-dependent features of future humans are exactly the reasons why ethicists in both traditions have sometimes argued strongly *against* the position that we have obligations to future generations. A quite large and serious scholarship exists which asserts we have NO duties to the future. For these thinkers, our duties to present humans *always and in every case* trump any duty we think we might have to future generations. These time-dependent features of future persons do not merely weaken any belief we have in obligations, they erase them. It is extremely important to point out that, as explained above, this position is not a viable one for the EPA to hold in defending its multiple-dose individual protection standard

17. Does this mean that if we assert we have duties to future generations, they will always be of the same strength as our duties to present persons or near-future generations?

No. The strength of our duties can differ. Unfortunately, the EPA's gloss of the scholarship in this field fails to allow them to understand the depth and complexity of the issues at hand.

To begin, the EPA asserts that "...there is no clear consensus regarding the extent of the claims held by the future on current generation (i.e. how many generations should be considered, how to compare their interests to those of the current generation, or what it means to 'compromise' their ability to take action.)" (EPA, p. 49036). This is an exaggeration and come close to building one's position on the *ad ignorantium* fallacy.

Instead, what one finds in the scholarship on intergenerational equity is agreement over some important distinctions that are not introduced by the scholarship in the NAPA report, the KASAM report and Chapman and McCombie. Those distinctions concern the difference between basic needs and welfare interests. It is this distinction that is used by both egalitarian and the consequentialist tradition. (In the scholarship, this distinction is often cast as basic human rights and welfare rights; however, the EPA Proposed Rules avoids language about the rights of future generations. I infer that they adopt the non-correlativity thesis regarding rights and duties, i.e. while legitimate rights beget legitimate moral (and legal) duties, legitimate duties exist without having to assert legitimate corresponding rights claims of non-existent persons. This lack of correlativity, by the way, is another reason why some ethicists assert we have no duties in the present to future generations).

Basic needs concern human survival (life) and health. Welfare interests are associated with the quality of life. Much of the concerns taking up in environmental ethics about intergenerational equity are related to welfare interests, i.e. in insuring a biodiverse world, in protecting environmental resources from depletion so that they may also be used by future persons, degrees of robust sustainability, etc. This is why the evolution in thinking in the received, peer-reviewed scholarship has turned to the provision of future opportunities and compensation for the lost of opportunities rather than the provision of specific resources. (DesJardins, p. 82) The emphasis on sustainability of resource utilization and trusteeship of the environment represents these concerns.

But, in the issue at hand, the EPA's proposed rules affect basic needs—preservation of life and protection of human health. It is sometimes the case that a present basic need will conflict with a future welfare interest. There is some agreement that basic needs of persons in the present trump future welfare interests if there are no alternative ways in which the basic need can be met. This fact of insuring that no alternatives are available is another moral trumping card even when basic needs in the present and the future are in conflict.

In applying this carefully to the issue at hand, the ethicist would want to know if the conflict is between 1) a present basic human need and a future human need; if so, this presents us with a moral dilemma , a truly thorny and complex ethical situation to confront, 2) a present welfare interest (often termed "wants") and a future basic human need, 3) a present basic human need and a future welfare interest, or 4) a present welfare interest and a future welfare interest. The nature of the interest will determine the how best to resolve the conflict. A determination must be made about the viability of alternative courses of action.

The grid below displays this conflict-resolution scheme:

Grid 1

Present Persons have:	**Future Generations have:**	**Resolution**
Present basic human need (need)	Future basic human need (need)	A moral dilemma which needs dissolution; dilemmas are, in principle, irresolvable
Present welfare interest (want)	Future basic human need (need)	Future trumps present
Present basic human need (need)	Future welfare interest (want)	Present trumps future
Present welfare interest (want)	Future welfare interest (want)	Present may trump future in some hierarchy of wants.

18. Using Grid 1, what must the EPA prove in order to better establish their ethical claim that it is morally permissible to require multiple dose standards in which less protection is given to future generations?

In the analysis above, the EPA must show that there are only welfare interests at stake to the future generations and that future generations' basic needs are not threatened; at the same time, they must show that basic human needs are at stake for present persons. However, if basic human needs are also at stake for future generations, we have a moral dilemma. A moral dilemma presents us with an apparent conflict between our moral duties, whereby following one transgresses on the other. A common way of handling a moral dilemma is to show that it doesn't really exist by dissolving one of the "horns of the dilemma." This is how some ethicist would handle the problem at hand, i.e. by denying that we have moral duties to future generations or by pointing out that perceived needs are really only wants. Another approach is to show that a proposed resolution, although not ideal is the greater of two goods or the lesser of two evils. In this instance, assuming present the present basic need for life and health conflicts with the far future basic need for the same, minimally, the EPA must clearly demonstrate that there is no feasible alternative to Yucca Mountain in order to override the basic needs of future generations to meet the basic needs of persons living in the present.

Finally, if only welfare interest are at stake for present persons, i.e. their life and health is not threatened but their interest in providing renewed energy resources is in jeopardy, the EPA would need to demonstrate that no life or health of far future generations are threatened. Grid 2 below represents the application of Grid 1 above:

Grid 2

Present Persons have:	Future Generations have:	Resolution
Basic human need to ensure equal protection of life and health from radiation exposure from HLNW at reactor and other sites	Basic human need to ensure equal protection of life and health from radiation exposure from breached nuclear repository	If there is no viable alternative to Yucca Mountain (if it cannot provide protection for both present and future generations), we have some hard choices to make for which there are no easy "principled" or "trumping" resolutions.
A welfare interest in promoting nuclear energy as a viable energy source for present persons.	Basic human need to ensure equal protection of life and health from radiation exposure from breached nuclear repository.	A multiple dose standard for the far-future generation **is not morally permissible**. Current welfare interests do not trump future basic needs.
Basic human need to ensure equal protection of life and health from radiation exposure from HLNW at reactor and other sites	A welfare interest only in promoting optimization of energy resources	A multiple dose standard that weakens the standard for the far-future generation **is permissible**.
A welfare interest in promoting nuclear energy as a viable energy source for present persons.	A welfare interest only, in promoting optimization of energy resources in the future	Present may trump future

A moral dilemma is represented by Row 1 above. Which "row" best describes the issue at hand is not merely a matter of interpretation or "words." Empirical evidence needs to be offered in support of the claims made in the relevant cells.

19. The EPA appeals to the KASAM State of the Art Report (1998) in which the assertion is made that because of increasing uncertainties "...our capacity to assume responsibility changes with time. In other words our moral responsibilities diminish on a sliding scale over the course of time." Chapman and McCombie also argue that time and uncertainties reduce our duties. What is wrong with this approach of coupling time with uncertainty to establish a reduction in duties?

No argument has been given by the EPA for why time alone weakens our duties to future generations. Chapman and McCombie, borrowing from economics, give credence to the use of discounting future interests in favor of present interests. (Chapman and McCombie, p. 53). Discounting takes account of the effect of time on the economy; analogically, the moral argument is to allow time to have its effect on our moral duties to future generations, thereby reducing or weakening them over time. However, there is widespread agreement among environmental economists and ethicists that discounting future generations interests, merely because they will live at a different time, is severely limited. . In fact, even the NAPA panel report (NAPA, Appendix B, p. 33) points this out. (Here, EPA has used sources which conflict with each other on this issue.)

The work of John Rawls, cited in some of the scholarship used by the EPA to support their Proposed Rules, would also deny the moral relevance of time in weakening our duties to future generations. For Rawls, the Original Position is not limited in time. Rawls says, "Now the contract doctrine looks at the problem from the standpoint of the original position. The parties do not know to which generation they belong or, what comes to the same thing, the stage of civilization of their society. They have no way of telling whether it is a poor or relatively wealthy, largely agricultural or already industrialized, and so on. The veil of ignorance is complete in these respects." (Rawls, p. 287). No future generation is more important than another as justice has no time preference. "The life of a people is conceived as a scheme of cooperation spread out in historical time. It is to be governed by the same conception of justice that regulates the cooperation of contemporaries. No generation has stronger claims than any other" (Rawls, p. 289). Each generation is obligated to save for the next (in terms of welfare) and each generation is obligated to maintain the same democratic institutions over time. Rawls points out, "We can now see that persons in different generations have duties and obligations to one another just as contemporaries do. The present generation cannot do as it pleases but is bound by the principles that would be chosen in the original position to define justice between persons at different moments of time. In addition, men have a natural duty to uphold and to further just institutions and for this the improvement of civilization up to a certain level is required...The original position is so defined that it leads to the correct principle in this respect...In the case of society, pure time preference is unjust: it means (in the more common instance when the future is discounted) that the living take advantage of their position in time to favor their own interests." (Rawls, p. 293 - 295)

We have seen above (13d) that uncertainties about the future that may be associated with time do not apply in this case and, therefore, do not provide a firm moral basis for weakening or reducing our duties to future generations.

20. Shouldn't uncertainty play some role in the moral life, in being ethical, and in creating ethical public policies?

Yes, it should. The authors of the KASAM report may, in fact, be correct in claiming that "increasing uncertainties means that our capacity to assume responsibilities changes with time." (KASAM, 1998, p. 27) However, a reduced capacity does not lead to the conclusion that "our moral responsibility diminishes on a sliding scale over the course of time." (ibid.) This distinction between ***capacity to assume or perform a duty*** and ***the strength of the duty itself*** is a significant distinction, overlooked by KASAM. The strength of duty itself remains the same, but the capacity to fulfill the duty may justify the shifting of the duty, in this case, from present generations to future generations if capacity increases by virtue of certain uncertainties decreasing with time.

In this case, uncertainties in repository performance are relevant to the question: *Who* has these responsibilities to future generations if current persons lack capacity? In other words, if uncertainties over time affect our *capacity* to ensure that an equivalent level of protection is met by a repository at a given site, and we have no alternative but this site (e.g. no other rock body can give us the assurances we need for the entire period from post-closure to peak dose period), then how can this responsibility to future generations be met?

Our *capacity* to assume those duties may, indeed, differ over time. Near and far future generations may be able to perform the duties better than we can in the present. They may have new technologies, reduced uncertainties, and expanded knowledge that time affords. Hence they may be able to do a better job of protecting human health in the future. The concept of the "rolling present" represents the fact that we transfer our duties over time; it does not represent the fact that we reduce them or weaken them because of uncertainty associated with time.

The concept of the "rolling present" emerged in the nuclear waste community as they were dealing with concerns that permanent reposition of nuclear waste did not leave open the ability to act on the solutions that the future might hold. If we cannot construct repositories now that will provide the same standard of protection to future generations as we provide present persons, then the rolling present allows us to transfer duties, along with resources and knowledge, without disenabling present persons or harming future generations.

A similar concept was introduced by John Rawls in order to help understand that our duties to future generations will need continuity over time. Others have introduced this concept of ensuring continuity in fulfilling our obligations, including the work cited in the KASAM report by Lars Ingelstram which calls for *an institutional constancy*. (KASAM, 1998, p. 25) KASAM states, "The question, Ingelstram argues, then becomes one of whether or not it is possible to bridge the time interval, or discover a link between the present and the future so that the comprehensibility and credibility can be preserved even for complex socio-technical systems designed to function for an extended period of time where we have no possibility to demonstrate that they will function as planned on the basis of the demands we make for long-term safety. Ingelstram claims that this link is *institutional constancy* by which he means the necessity to build in control mechanisms in society's institutions to continuously test to see if promised results are achieved." (p. 26).

KASAM points out that geologic disposal has been thought to provide the stability needed to protect human health from radiation exposure due to a repository breach. Not too long ago the nuclear waste community found this appeal to obligations to future generations both morally praiseworthy and politically effective. However, as we come closer to realizing the complexities and uncertainties associated with repository performance, unless alternative sites and alternative engineering is available to restore such stability, we have shifted to a concept of "the rolling present" that is thought to displace some of our obligations onto the future. As I pointed out in No. 13 above, the EPA is not empowered to respond to the demands for institutional constancy required by a rolling present.

In an earlier report by the Alternative Group in Sweden, this idea of a rolling present surfaced but it was coupled with a warning that this would require a new way of approaching the regulatory requirements for nuclear waste disposal. In this same publication, the question of how long the present rolls is raised. The response points out that it is a phenomenon which, in practice, began when the first reactor was created and ends when an irrevocable decision is made, most likely when the repository closes and the waste becomes difficult to retrieve. Swedish citizens are asked to contemplate "which decisions can with a rolling present be left to future generations and which decisions are they qualified to make in the near future." (Nilsson, p. 32.) This demonstrates the lack of fit of this concept for the EPA's task at hand. The EPA is not authorized to delay the decision on protection standards and the multiple dose standard they propose does not reflect the need for a rolling present.

To be clear, were a shift in the locus of moral responsibility needed, it does not change the strength of the moral duty we have to provide equal protection to individuals from harm (no matter how "negligible") to their basic need for health. As Richard Howarth points out in his article "Intergenerational Justice and the Chain of Obligation," the links made among succeeding generations are equally strong. Our link to the children of today, a presently living but nevertheless different generation than our own, is just as strong as the subsequent links made between our children and theirs, and their children's children and the children of these children's children and so forth. The strength of the link doesn't weaken merely because they live later in time from us. They bear the same strength in the link between the succeeding generation and theirs. Our place in the chain doesn't weaken their link (i.e. their duties).

If we believe *our* children should be exposed to no more that 15mrem/a, there is no reason for us to think and act in such a way that our distantly-related generations should not also be exposed to no more than 15mrem/a. Why would the child who lives on January 1, 10,001 be entitled to less protection than our children today? What we believe to be just in our relations to our contemporaries should be extended to define standards of just distribution between generations. "To the extent that principles of justice require equal treatment for contemporaries, they require equal treatment for future generations as well" (Howarth, p. 135). The chain of obligations does not weaken our duties to future generations; it does just the opposite: it establishes those duties as equally strong across generations

Understanding this comes from untangling the distinction between our **capacity to fully assume our duties** and **the strength of the duties themselves**. These two aspects of the moral life must not be confused with each other.

21. The EPA Proposed Rules lists three gradations of principles of justice: strong, weak, and minimal. What is wrong with thinking that we can apply a "Strong Principle of Justice" a "Weak Principle of Justice" and a "Minimal Principle of Justice" to the various time periods from post closure to peak dose and associate differing standards of protection to such time periods?

These principles of justice are relatively unfamiliar. They are not found in the scholarship of American ethicists or scholars of social justice. Nor are they found in the reference cited by EPA. A document search of Philosopher's Index, which indexes all the major and minor journals from the present backward, revealed no scholarship with titles or abstracts using these three principles. A "Google" search also came up with no results for this combination of strings. The expression 'minimal principle of justice' is common in justice scholarship but it only refers to the principle "Treat like cases alike." After considerable search, this distinction was finally found buried in the third chapter of Mikael Stenmark's *Environmental Ethics and Policymaking* (Studentlitteratur, 2000) originally published in Swedish and recently translated into English (by Ashgate Press, 2002).

The EPA adopts these principles from a later KASAM report (2004). In Chapter 9 of this report, which is coauthored by Stenmark, his four principles are introduced. His purpose, in Chapter 3 of the earlier work, is to explain just sustainability.

> Static Principle of Justice: *We have a moral obligation to pass on to subsequent generations the same quantities and type of natural resources that our own generation inherited from previous generations.*
>
> Strong Principle of Justice: *We have an obligation to use or consume natural resources in such a way that subsequent generations can be expected to achieve a quality of life equivalent to ours.*
>
> Weak Principle of Justice: *We have a moral obligation to exploit natural resources in such a manner that not only the present generation but also future generations can satisfy their basic needs (i.e. need for food and water, protection against weather and wind, and access to work, health care, and education.*
>
> Minimal Principle of Justice: *Intrusion into the natural order of things is a human right. However, we have a moral obligation to exploit or consume natural resources in such a way that we do not jeopardize future generations' possibilities for life.*

These principles of justice are placed on a spectrum, which "is based on a scale which deals with the consequences of the present generations' patterns of consumption and use of natural resources. Certain principles of justice would – if applied consistently – result in radical changes in our consumption patterns and use of natural resources." (KASAM, 2004, p. 433)

Arguing that we have a diminishing moral responsibility, the authors clarify this to mean the following: "Our main thesis is that we should have a more extensive duty towards generations in our immediate future – and apply the strong principle of justice – and a more limited duty toward distant generations – and apply the weak principle of justice" (p. 436). Then, they ask, why in the very far future do we need only apply a minimal principle of justice? Changing over from one principle to another on this spectrum is justified by the "lack of ability to assess or influence, in a reliable manner, the needs that those generations will have in terms of energy, transport, housing, education, etc." (436).

These principles are mapped onto a timeline and in turn applied to the disposal of nuclear waste. The static principle, rejected by the authors, would not allow any disposal to take place—and would most likely not have allowed the intrusion into nature in the first place to extract uranium for the production of nuclear energy, which ultimately produced the waste. At the other end of the spectrum, the minimal principle of justice is mapped to the very far future.

Whether this "spectrum approach" to just sustainability and its mapping onto time is defensible is a matter for scholars of environmental ethics and other scholars to explore. However, whether its subsequent application to the nuclear waste issue ***in the way used by the EPA*** holds up under critical scrutiny is highly doubtful, given the discussion above. The EPA states "In the case of spent fuel disposal, these considerations lead to the idea that a repository must provide reasonable protection and security for the very far future, but this may not necessarily be at levels deemed protective (and controllable) for the current or succeeding generations."(EPA, p. 49036) This statement does not follow from any one of these principles. We must conclude that the principles in the KASAM Report (2004) do not support the creation of the multiple dose protection standard proposed by EPA. This is because, as we have said above,:

1. We do not lack the ability to assess the needs of future generations regarding protection from radiation (unless we want to stipulate either ignorance of or changes in human physiology, genetic structure, etc. which EPA is unwilling to make).

2. EPA protection standards are not about welfare interests in energy, transport, housing, education. They are about the most basic, fundamental interest a human has--in his/her preservation of life.

3. The multiple dose protection standard proposed by the EPA jeopardizes future humans' possibilities for life. We know that 350 millirems will provide less protection and greater risk of deaths in the future than 15 millirems will in the present. Hence, the multiple dose standards are not even justified by the minimal principle of justice.

4. The multiple dose protection standard proposed by the EPA is, in fact, "off the map" or one that lies outside the spectrum of these 4 principles.

5. The multiple dose protection standard proposed by the EPA is supported, instead, only by the very position rejected by the KASAM Report (2004), i.e. Andrew Kadak's view that "we have an obligation to protect future generations provided the interests of the present and its immediate offspring are not jeopardized." (KASAM, p. 432). The KASAM authors point out that "even the weak principle of justice does not allow us to prioritize all our interests without further ado. According to the weak principle of justice, the basic needs of future generations take precedence over the current generation's interest, which extend beyond our basic need for work, food, energy, housing, health care, and education. (ibid.). This comparison of basic needs and interests is provided above.

22. Do these principles, in their original formulation, support the EPA's Proposed Rule?

First, it is important to point out that these principles are intended to apply to the ethics of sustainability and, in particular, the just allocation of resources across generations. The EPA Proposed Rule is not about sustainability, except in the very narrow sense of sustaining the life and health of future generations. Work by ethicists on sustainability concern much broader issues, such as increased population and increased consumption. Stenmark's principles attempt to justify the different duties we have to provide these resources to differently situated generations in time.

Second, if pressed to apply these principles to the question of radiation standards of protection of human health and life, one must conclude that these principles would not support a multiple dose standard that would put far future generations at greater risk than present ones. This is simply because the most minimal of principles can be interpreted, as Stenmark himself does in the concluding paragraph of his original work, as follows:

> 'Without compromising the ability of future generations to meet their own needs' can imply that they should be so equipped...that at least they can ensure their survival: in other words, we do not expose them to radioactive radiation or radioactive waste, dramatic natural catastrophes, or severe alterations of climate (Stenmark, p. 56)

From this, it is doubtful that any of these principles, even the one that provides the barest standard of sustainability (Stenmark's minimal principle of justice), would actually support different standards of protection of life and health, i.e. allow greater risk to the far future than to the present and near future.

23. What should the EPA have provided in 40 C.F.R. 197 in its discussion of intergenerational equity?

In order to gauge the social acceptability of a particular expression of intergenerational equity through its comment period, the **EPA needed to have followed the NAS Committee's recommendation more closely and *also* addressed whether future generations should have *greater* or *equivalent* protection**. The reader is only able to *infer* from the 40 C.F.R. 197 that society does not have a greater or equivalent duty to future generations but he or she has not be offered good reasons to accept this inference.. Unfortunately and without intending it , in 40 C.F.R. 197, the EPA's examination of this matter comes perilously close to "cherry picking", i.e. mustering only those arguments to support the lesser duty, albeit from scholarship provided by entities with vested interests in solving one of this nation's most challenging environmental issues. This approach does not tell the reader *why* the duties are not greater or equivalent. A more balanced approach to the EPA's proposed rule-making and one clearly recommended by NAS (NAS, 1995, p. 56) , would have been to also muster arguments in support of the other two positions and then explain why the "lesser duty position" is morally preferable.

Again, this is especially important not because there is controversy about this matter. The two unexamined positions of equivalent or greater protection are more strongly held by members of society. The moral intuition of most persons (and replete in the literature) is that if uncertainty surrounds a situation of potential risk to something as basic as life and health from radiation exposure or if future persons must bear risks with only indirect benefits, it is best to provide greater or equivalent protection, *not less protection*. These more commonly accepted societal expressions of intergenerational equity were not addressed. The EPA proposal is lacking in this regard in 40 C.F.R. 197.

24. What are the ethical problems with using Chapman and McCombie's approach that we should return to nature for standards in the long term?

EPA refers to these authors to support the view that natural background radiation levels should be normative for determining standards in the long term. These authors support their position with the following reasons:

1. "...there is a strong case, based on the parallel with nature, on society's real expectations and on sensible use of resources for saying that we have done enough." (p. 114)

2. "There is no logical or ethical reason for trying to provide more protection than the population already has from Earth's natural radiation environment in which it lives and evolves." (p. 114)

3. "It is a scientifically tenuous position to argue that additional protection (e.g. down to a few microsieverts of exposure) can be provided so far into the future and that this can be ensured by regulations." (p. 114)

Having listened to the nuclear waste community for decades, I know full well how difficult it is for some of its members to see that the appeal to nature is, first and foremost, logically problematic because it commits a fallacy. This fallacy rests on the fact that, (as I mentioned above in connection with an appeal to a "natural tendency" in moral psychology), it illicitly attempts to derive "ought" from "is." What is missing is a defense of the enthymatic (suppressed) premise "Nature is good" (or in this case, 'Exposure to radiation from natural background is good.')

But the argument presented by Chapman and McCombie has further problems. The first reason above is nothing more than *ad populum* or an appeal to popular beliefs, assuming that this belief is indeed true, i.e. that society does not expect regulations to provide greater protection from radiation than what we receive from the natural background. There is, of course, very good reason to believe that society has not assented to this level of radiation. Numerous radiological protection standards which set limits below natural background exist. Additionally, there is considerable difference between measuring society's expectations by what it lives with out of ignorance, unintentionally, or passively, and measuring society's expectations by its intentional, active acceptance, through referendum, or some other means for assessing its expectations.

This argument is similar to the one discarded by environmental ethicists, that persons actively assent to certain beliefs over others through the market place and therefore, we have no obligations to our environment other than those reflected in purchasing patterns. This collapses an important distinction between person as consumers, acting from certain desires and persons as citizens, operating on certain beliefs. (Sagoff, 1990)

The second reason is simply false. As I've already pointed out there are both logical and ethical reasons for trying to provide more protection than we already have from Earth's natural radiation environment. Not only is the argument fallacious (and therefore, illogical) but also humans' interest in protecting their health and improving it are supported by the principles of non-malfeasance and beneficence.

The third reason introduces a straw man. The regulation proposed (15 mrem/a) does not place undue burden on science for at least up to 10,000 years. Whether it does so for the repository at Yucca Mountain beyond 10,000 years does not mean that it would do so for all potential repository sites.

25. Notwithstanding the above comments on problems with setting a multiple dose standard that differs for present, near future and far future persons, the EPA set the individual protection standard for far-future generations at 350m/rem/a. How would it know if this expression of intergenerational equity is socially acceptable?

The EPA assumes a responsibility of significant proportions by trying to set a radiation protection standard that reflects the judgment of society regarding intergenerational equity. In doing so, not only does it have the attendant responsibility to consider whether future generations should receive more, less, or equivalent protection, but it also must have some **clear criteria** (absent a national referendum) for determining which expression of intergenerational equity is socially acceptable and it must translate that expression into a radiation protection standard. "Societal acceptability means that decisions are justified by agreed criteria and procedures for decision making." (NAS/BRWM Committee on Disposition of High-Level Radioactive Waste through Geological Isolation, "Disposition of High-Level Waste and Spent Nuclear Fuel", 2001)

* * * * * * * * *

In conclusion, justice and fairness requires that we begin with the presumption that present, near and far future generations all deserve equal protection to a basic need such as health and life; our duties to them are equally strong; equality establishes equity in this case. If we want to claim differently, i.e. that they are stronger to some generations than to others it must be because of a morally relevant difference to secure equity. For example, NAS suggests that direct benefit accrual is one such difference. Even that has to be justified with good argument—it should not be simply asserted. Moreover, if one's duties are weak to some generations but not to others, then a morally relevant difference must be identified and justified. It is the well-reasoned view that will ultimately win social acceptability. Despite the valiant attempts to use the scholarship in ethics found within the nuclear waste community, for the many reason cited above, we haven't been presented with a well-reasoned position in the EPA Proposed Rules of August 22, 2005.

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Biographical Information

Dr. Patricia Ann Fleming is a professional philosopher by training with a specialization in applied ethics and philosophy of science. (M.A. and Ph.D. from Washington University, St. Louis). She teaches Environmental Ethics regularly at Creighton University and is the Senior Associate Dean of the College of Arts and Sciences. Dr. Fleming publishes and lectures nationally and internationally on the ethical and epistemological issues associate with high level nuclear waste disposal. Her familiarity with the many ethical and epistemological issues of HLNW disposal spans the period from approximately 1979 – 2005. She has participated in VALDOR and is a board member of VALDOC and has been performed the functions of a thematic rappatouer for the NEA/OECD Forum on Stakeholder Confidence in Ottawa, Canada. This familiarity with ethical concerns regarding the health effects from radiation exposure led to her appointment on the NAS Committee to Assess the Scientific Information for the Radiation Exposure Screening and Education Program. She has recently been nominated to serve on the national Veteran's Board on Dose Reconstruction, established by Congress

Dr. Fleming has friendly acquaintances with individuals from "both sides of the aisle". These connections, necessary to accomplish her scholarship as an applied ethicist, do not prevent her from examining the issue below with impartiality. Dr. Fleming does not have a conflict of interest with either the State of Nevada or the Environmental Protection Agency.

Appendix E

Mike Thorne and Associates Limited

(Director: Dr M C Thorne)

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External Memorandum

Date: 10 November 2005
From: M C Thorne
Subject: Climatic Considerations relevant to the Draft EPA Rule

The draft EPA Rule (page 49058 *et seq.*) gives consideration to how climate change should be represented beyond 10,000 years. EPA is 'concerned about the possibility of over-speculation of climatic change over such extremely long time periods, possibly out to the next 1 million years.' In support of its position, it cites the NAS Report (page 77) as stating:

'Although the typical nature of past climate changes is well known, it is obviously impossible to predict in detail either the nature or the timing of future climate change. This fact adds to the uncertainty of the model predictions.'

This is the beginning of a more extended commentary on the influence of climate provided in the NAS Report (pages 77 and 78). The paragraph immediately following that cited above is given in full below. The references cited are given in full in the NAS Report.

'During the past 150,000 years, the climate has fluctuated between glacial and interglacial status. Although the range of climatic conditions has been wide, paleoclimatic research shows that the bounding conditions, the envelope encompassing the total climatic range have been fairly stable (Jannik et al., 1991; Winograd et al., 1992; Dansgaard et al., 1993). Recent research has indicated that the past 10,000 years are probably the only sustained period of stable climate in the past 80,000 years (Dansgaard et al., 1993). Based on this record, it seems plausible that the climate will fluctuate between glacial and interglacial states during the period suggested for the performance assessment calculations. Thus, the specified upper boundary, or the physical top boundary of the modeled system, should be able to reflect these variations (especially in terms of ground water recharge).'

The NAS Report provides further discussion of the role of climate change at Yucca Mountain at pages 91 to 92. Three main potential effects of climate change on repository performance are identified. 'The first of these is that increases in erosion might significantly decrease the burial depth of the repository. Site-specific studies of erosion rates at Yucca Mountain (DOE, 1993b) indicate that an increase in erosion to the extent necessary to expose the repository (even over a million-year time scale) is extremely unlikely.' The third type of change that might result from climate change is a shift in the distribution and activities of human populations. However, this matter is addressed through the specified definition of the exposed group and is not considered further here. The second type of change relates to the flux of water through the unsaturated zone. The comments from the NAS Report on this matter are reproduced in full below.

'Change to a cooler, wetter climate at Yucca Mountain would likely result in greater fluxes of water through the unsaturated zone, which could affect rates of radionuclide release from waste-forms and transport to the water table. Little effort has been put into quantifying the magnitude of this response, but a doubling of the effective wetness, defined as the ratio of precipitation to potential evapotranspiration, might cause a significant increase in recharge. An increase in recharge could raise the water table, increasing saturated zone fluxes. There is a reasonable data base from which to infer past changes in the water table at Yucca Mountain. Although past increases under wetter climates are evidenced, a water-table rise to the point that the repository would be flooded appears unlikely (Winograd and Szabo, 1988; NRC, 1992; Szabo et al., 1994). Additional site characterization activities and studies of infiltration at Yucca Mountain should help improve estimates of the bounds of potential hydrologic responses to climate change. It should also be noted that the subsurface location of the repository would provide a temporal filter for climate change effects on hydrologic processes. The time required for unsaturated zone flux changes to propagate down to the repository and then to the water table is probably in the range of hundreds to thousands of years. The time required for saturated flow-system responses is probably even longer. For this reason, climate changes on the time scale of hundreds of years would probably have little if any effect on repository performance, and the effects of climate changes on the deep hydrogeology can be assessed over much longer time scales.'

The EPA Draft Rule (pages 49058-49059) reiterates and endorses the above comments and also includes a brief summary of the infiltration modeling undertaken by the DOE. It then states that the EPA believes that 'an approach should be developed to answer several basic questions about how climatological effects realistically will impact the proposed repository until the time to peak dose. The questions that concern us are:

1. How much total water will infiltrate into the repository over this large amount of time?
2. Will more water infiltrate the repository over time when modelled as a wave function (current DOE modelling) or as total average?'

The conclusions drawn by the EPA as to how these questions should be addressed are reproduced, in full, below from pages 49059-49060 of the Draft Rule.

'The answers to these questions assist in identifying conservative, yet reasonable, conditions the repository may encounter over the period of geologic stability. The amount of net infiltration into Yucca Mountain has an effect on the disposal system performance because higher net infiltration leads to the possibility that a greater proportion of the repository will experience ground-water seepage. For solubility-limited radionuclides in the waste, an increase in net infiltration could lead to a higher release rate of radionuclides from the disposal system, thereby affecting the potential dose to the RMEI in the accessible environment. We do not believe that it is important to know or predict with certainty precisely when the climate states with peak precipitation occur during the modeling. There are too many uncertainties and permutations available in trying to project a future set of climate conditions, and it is difficult to place specific times on when discrete pulses of precipitation should be injected into the modeling (NAS Report p. 77). Instead, we believe that it is reasonable to assume an average increase in precipitation over the entire time from 10,000 years through the period of geologic stability, and to model those consequences. An increase in average precipitation throughout the period of geologic stability is a more reasonable approach because it assumes a constant source of precipitation, creating more downward flow that will eventually reach the repository. This scenario need not be dominated by highs or lows in precipitation over the time period and does not require speculation about the exact timing or transient effects of shifts in climate. Rather, setting a constant value somewhat higher than today's average annual rainfall and extending it out to the time of peak dose would account for the greater potential for available fluids at the time of the failure of the waste packages. We believe that this approach provides a reasonable test of the repository conditions out to the time of peak dose, and will give a more conservative idea of potential fluid flow, as well as potential for migration of radionuclides out of the repository.'

'We are proposing today that DOE, based on past climate conditions in the Yucca Mountain area, should determine how the disposal system responds to the effects of increased water flow through the repository as a result of climate change. We believe that the nature and extent of climate change can be reasonably represented by constant conditions taking effect after 10,000 years out to the time of geologic stability. We are proposing to explicitly require that DOE assume water flow will increase as a result of climate change. We leave it to NRC as the licensing authority to specify the values to be used to represent climate change. However, we expect that a doubling of today's average annual precipitation beginning at 10,000 years and continuing through the period of geologic stability would provide a reasonable scenario, given NAS's statements regarding potential effects on recharge (NAS Report p. 92). NRC could also use the range of projected precipitation values for different climate states and specify a reasonable long-term average precipitation based on the duration of each climate state over the period of geologic stability. We believe that either approach will allow for a reasonable estimate of how water will impact the site without subjecting the assessments to speculative assumptions that may well be unresolvable, while providing a reasonable indicator of disposal system compliance. NRC might choose to express the ground-water flow effects directly as infiltration rates or other representative parameters, avoiding the necessity of translating precipitation and other climate-related parameters (e.g., temperature or evapotranspiration rates) into infiltration.'

The EPA comments reproduced above make two very broad assumptions about climatic and hydrologic behavior at Yucca Mountain. These are that:

1. Future climatic conditions at Yucca Mountain can be bounded by the observed range of conditions over past glacial-interglacial cycles;
2. Only long-term average responses of the system to changes in infiltration are of relevance.

We contend that neither of these conclusions has been adequately substantiated, but that both can be investigated using current and developing techniques that would command substantial support in the scientific community.

This memorandum does not address the response of the system to changes in infiltration rate in any detail. However, it is a characteristic of arid zone hydrological systems that hydrological response is highly non-linear. For frequent events, almost all of the precipitation that falls is subsequently lost to evaporation, so runoff and groundwater recharge are very limited. Extreme storm events occur infrequently, but tend to dominate runoff production and groundwater recharge. Therefore, inter-annual variability of precipitation leads to much greater inter-annual variability of runoff and recharge, and annual runoff and recharge can be dominated by a single large event.

The dominant effects of extreme events have been widely noted in the historical literature. For example, Drissel and Osborn (1968) reported for Alamogordo Creek in

New Mexico that 60% of a decade's runoff was produced in a single year. Osborn and Renard (1969) observed for Walnut Gulch, Arizona, that runoff from a single storm in 1967 accounted for more than 80% of the runoff for the year and 50% of the total runoff from a three year period. They noted that 'the exceptional events are extremely important in studies of water yield….'

For Yucca Mountain, Woolhiser *et al.* (1998), reporting to NRC, simulated runoff and channel infiltration for Solitario Canyon based on a generated 100 year precipitation series. They concluded that, depending on the parameters selected, between 16 and 24 events in the 100 years accounted for 75% of the runoff, and between 31 and 35 events accounted for 75% of the infiltration. Stothoff (1999) used a simpler modeling approach (a 1-dimensional soil model; see also Stothoff *et al.* (1996)), but also observed a highly nonlinear response of net infiltration to climate: 'The exponential response of net infiltration to climate change suggests that cumulative net infiltration may be underestimated unless perturbations in the climate cycle are considered.' The 1997 Unsaturated Zone Flow Modeling Expert Elicitation Panel (CRWMS M&O (1997)) felt that events occurring once in 10 or 20 years would dominate net infiltration.

Clearly, extreme events dominate hydrological response and any changes in extremes will have disproportionate effects on runoff and net infiltration.

By the use of appropriate hydrogeological modeling techniques, it is possible to evaluate the flow of water through both the unsaturated and saturated zones at Yucca Mountain under time-varying boundary conditions. Therefore, the issue of timescales of response of the system to changes in boundary conditions can be investigated directly and should not be considered to be either a matter of speculation or requiring prior prescription. Furthermore, it should be noted that the radiological impact of hydrological changes is not simply determined by the cumulative influx of water through the system, but by the influx on timescales comparable with those for water flow through the system. In a recent report to the EPA, S Cohen & Associates (2005, pages 2-8 and 2-9) has stated that:

'The percolation flux in the UZ [Unsaturated Zone] is not expected to be constant with time, but may increase episodically as a result of high-infiltration events, seasonal variations, and climate changes.

Episodic flow events may affect seepage in two ways:

(1) Episodic flow events lead to periods when percolation fluxes (and thus seepage rates) are greater than the corresponding average values.
(2) Episodic flow events lead to transient effects (such as storage and hysteresis).

UZ modeling handles temporally increased percolation fluxes by applying episodic-flow factors in a way similar to the flow-focusing factors (CRWMS M&O 2000e, Section 6.3.4). Currently, no evidence shows that high-frequency fluctuations (a few years or shorter) penetrate to the depth of the potential repository. Flow simulations have shown that the nonwelded PTn rock unit effectively damps out flow transients. The TSPA-SR analysis explicitly accounts for increased percolation from long-term transients (climate change).'

This citation does not rule out the potential significance of transient effects on groundwater flow through the unsaturated zone on timescales of more than a few years. Also, as noted by S Cohen & Associates (2005, page 8-1), 'transport time through the SZ

[Saturated Zone] for dissolved, nonsorbing, nonreactive radionuclides can be less than 100 years'. As the DOE considers that the water table is 'now at a low point in the 150,000-300,000 years climate cycle' (S Cohen & Associates, 2005, page 8-16), it seems more likely that transit times will decrease in future rather than increase.

Finally, on this point, we note that Figure 3.2.1-1 from Volume 2 of the SSPA (2001) (reproduced below as Figure 1) demonstrates that annual doses assessed using the TSPA can respond very rapidly to changes in climate. In a study in which the times of climate transitions were fixed for every realization, the changes in response arose almost instantaneously in nearly all those realizations. As a basis for interpreting this figure, it should be noted that, in the Extended Climate Model, there is no change in climate state from 2,000 years to 38,000 years, which is when the first glacial period (increased infiltration) is estimated to occur. The next glacial periods occurs at 106,000 years and 200,000 years. Glacial periods are 8,000 to 40,000 years in duration and recur approximately every 90,000 years, on average.

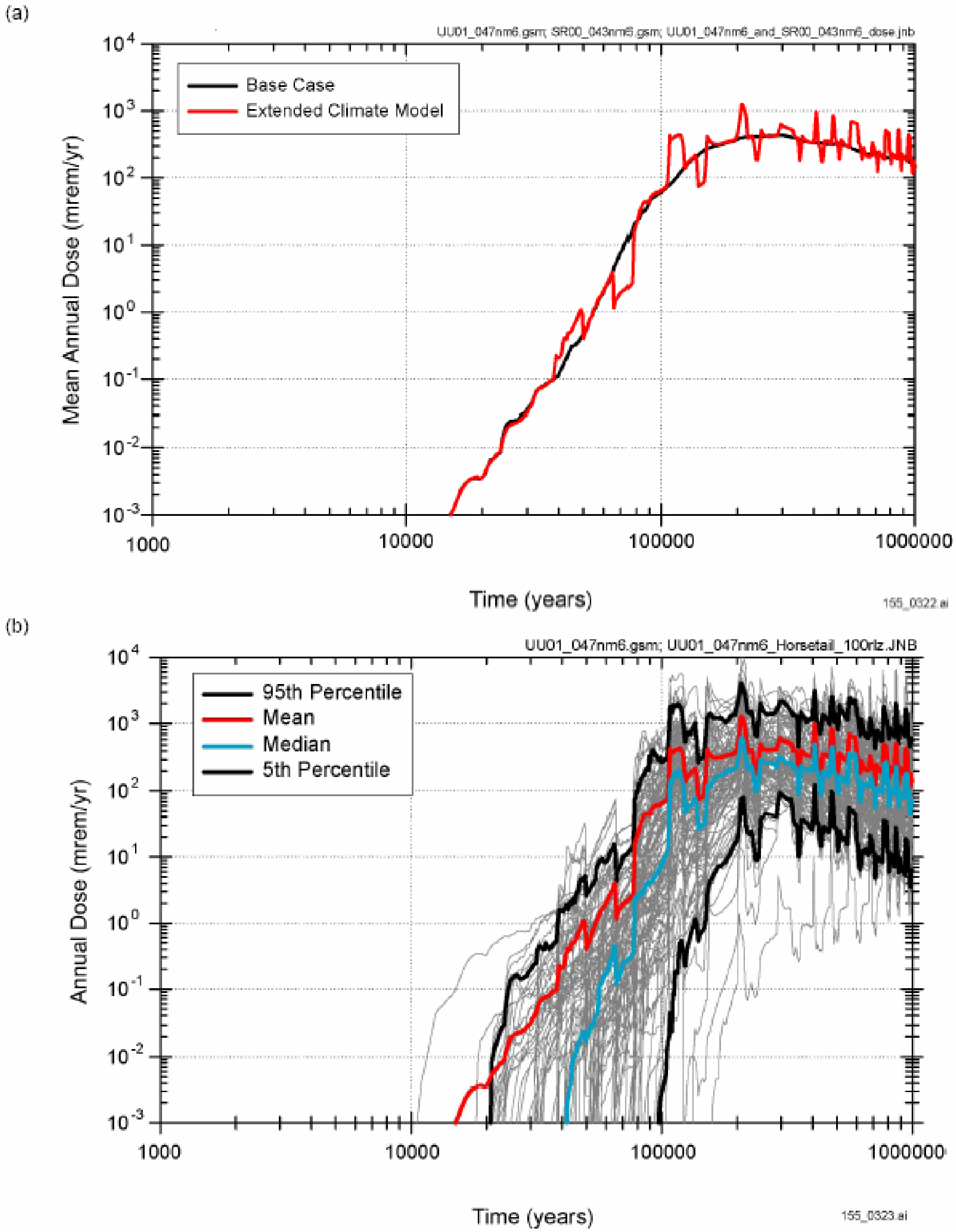

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Figure 1: Figure 3.2.1-1 from Volume 2 of the SSPA, illustrating Annual Dose Histories from the Extended Climate Model and the Base Case (The Base Case Model exhibits a constant climate state beyond 10,000 years, whereas the Extended Model exhibits climate transitions at specific times, as described in the text.)

Thus, the consideration arises as to whether the EPA Draft Rule has given adequate consideration to the range of future climate changes that could occur. The main issue that has to be addressed is the total lack of consideration of the potential for anthropogenically induced climate change due mainly to the carbon dioxide released as a consequence of the burning of fossil fuels.

Anthropogenic releases of carbon dioxide are generally considered likely to have long-lasting consequences for the carbon cycle of the Earth. Though other greenhouse gases, like methane or nitrous oxide, may have some influence on climate over the coming decades or centuries, only carbon dioxide has a lifetime in the atmosphere of many millennia. This is why understanding the evolution of atmospheric carbon dioxide concentrations is a top priority in climate change studies.

Systematic atmospheric measurements performed since the 1950s have demonstrated a very rapid increase in carbon dioxide concentrations, from about 320 ppm in the 1950s to nearly 380 ppm nowadays. This additional carbon has been unambiguously traced to arise from fossil fuel sources (Houghton *et al.*, 2001), and the now available long carbon dioxide history from Antarctic ice cores tells us that pre-industrial levels were approximately around 280 ppm, already a maximum value for natural carbon dioxide levels during the Quaternary (Petit *et al.*, 1999). There is now wide acceptance that these increased greenhouse concentration levels will significantly warm our planet during the 21^{st} century and also almost certainly during the 22^{nd}, depending on the availability of fossil fuels, on the economic choices made and on possible future technological breakthroughs in the production of cheap energy that does not rely on fossil fuel combustion (Houghton *et al.*, 2001). Currently, the focus of climate change research is on the future decadal or century scale, and more limited work has been performed on possible longer-term consequences. Furthermore, the available resources of fossil fuel are limited and, under most economic scenarios, would result in declining use in, at most, a few centuries. Is this anthropogenic carbon of significance when considering a very long-term future perspective? It is, because even though a large part of the fossil fuel carbon will, within centuries, be absorbed by the ocean, a non-negligible fraction, between 5 and 10% of the total amount, will remain in the atmosphere for a period measured in hundreds of thousands of years (e.g. see Archer *et al.*, 1997; Archer, 2005). Depending on the size of the anthropogenic perturbation, this remaining fraction could have a direct influence on the occurrence of future glacial-interglacial cycles.

The potential evolution of atmospheric carbon dioxide concentrations over the long-term and the associated implications for climate change have been investigated in the context of deep geological disposal of radioactive wastes in Europe in the BIOCLIM program (funded by the European Union and involving radioactive waste management organizations from the UK, France, Spain, Germany and the Czech Republic, as well as the UK Environment Agency and academic climate research centers from various countries).

In BIOCLIM, future variations in natural carbon dioxide concentrations in the atmosphere, i.e. excluding anthropogenic influences, were estimated using statistical regression techniques or a simple threshold model (BIOCLIM, 2001). This work was based on the extensive knowledge that has been developed over the last few decades on variations in atmospheric carbon dioxide concentrations that have occurred over the last few hundred thousand years.

Imposed upon these natural variations are the changes in carbon dioxide concentrations that arise from human activities, primarily the burning of fossil fuels. Future increases were estimated in BIOCLIM (2001) for two emissions scenarios (low and high), based on different projections of future fossil fuel use, combined with a model-based relationship between the amount of carbon introduced into the atmosphere as carbon dioxide and the time-dependent concentration of carbon dioxide in the atmosphere arising in consequence. The relationship used had components with atmospheric mean residence times of 3.65×10^2, 5.5×10^3, 8.2×10^3 and 2.0×10^5 years, so the long-term effects of fossil fuel combustion on atmospheric carbon dioxide concentrations were projected to persist for timescales corresponding to several glacial-interglacial cycles.

Finally, to define overall scenarios for future variations in concentrations of atmospheric carbon dioxide, the contribution from fossil fuel combustion had to be combined with the projected natural variations. As it was unclear whether the fossil fuel component would be subject to temporal modulation in the same way as the natural component, two different approaches to combination were used. However, comparison of the results obtained showed no strong distinction between the two approaches. Furthermore, there was also no strong distinction between the scenarios generated using the statistical regression and threshold models for variations in natural carbon dioxide concentrations (BIOCLIM, 2001). Therefore, only three scenarios were carried forward for detailed consideration. These all used the threshold model for variations in natural carbon dioxide concentrations and did not modulate the fossil fuel contribution according to variations in the natural concentration. These three scenarios were:

- Scenario A4: Natural variations only with no post-industrial, i.e. after 1850 a.d., contribution from fossil fuel combustion;
- Scenario B3: Natural variations plus a contribution from the fossil fuel scenario with low future utilization of fossil fuels;
- Scenario B4: Natural variations plus a contribution from the fossil fuel scenario with high future utilization of fossil fuels.

Both low and high utilization scenarios were consistent within known, economic resources of fossil fuels.

Results from this analysis for Scenarios B3 and B4 using both the summing and scaling approaches to natural carbon dioxide concentrations are shown in Figure 2. Although there is room for considerable variation in the choice of emissions scenario selected for study, as well as the approach adopted for combining natural and anthropogenically induced variations, the general conclusions from this work are thought to be reasonably robust. Specifically, atmospheric concentrations of carbon dioxide are projected to peak at 1000 to 2000 ppm, compared with a pre-industrial value of 280 ppm and a present-day value of 380 ppm, at about 300 years After Present (AP). They are then expected to decrease gradually, but not to fall to pre-industrial levels, on a long-term basis, until more than 300,000 years AP.

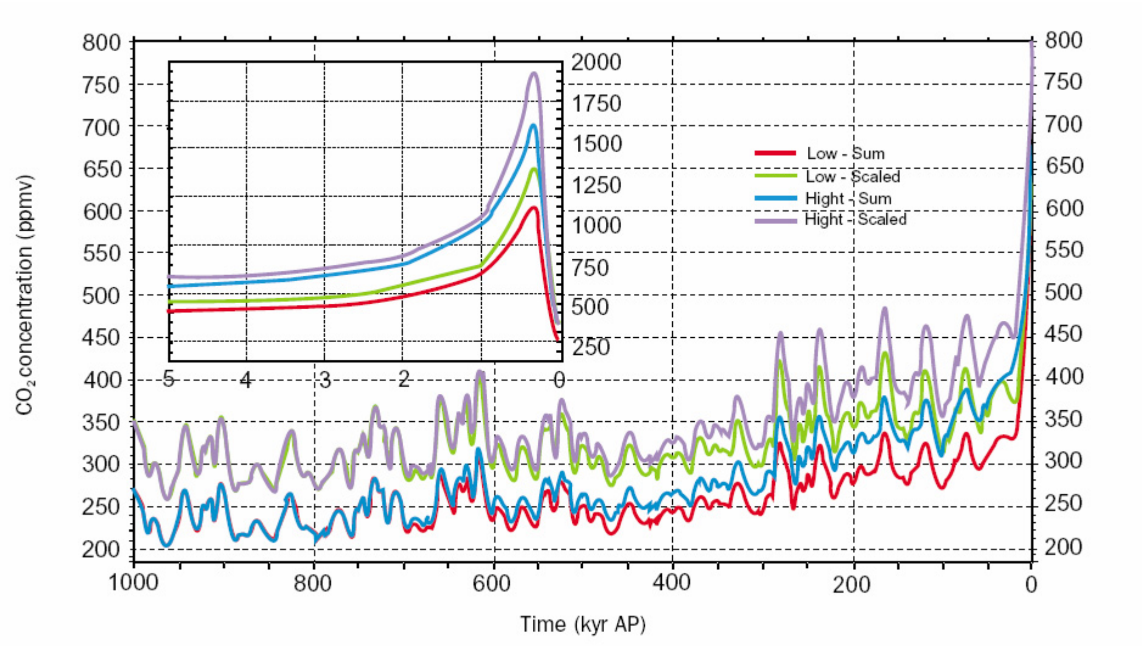

Figure 2: Atmospheric Carbon Dioxide Concentrations simulated in BIOCLIM. Reproduced from BIOCLIM (2001). Note that the time axis runs unconventionally from right to left and that kyr AP is thousands of years after present. The inset shows details of atmospheric concentrations over the next 5000 years.

In BIOCLIM, these scenarios were then used to investigate the potential range of long-term climatic conditions that could occur over Europe driven by both the changes in carbon dioxide concentrations and variations in insolation arising from changes in the orbital characteristics of the Earth (see, for example, Figure 3). The approach used involved the application of various types of climate model. Long-term transient simulations were undertaken, for timescales of either 200,000 years or one million years, using three different Earth Models of Intermediate Complexity (EMICs) (for a review see Claussen *et al.*, 2002). These were LLN 2D NH and MoBidiC, developed by the Institut d'Astronomie et de Géophysique Georges Lemaître, Université catholique de Louvain, Belgium (Gallée *et al.*, 1991; 1992; Crucifix *et al.*, 2001), and CLIMBER-GREMLINS, developed by the Commissariat à l'Energie Atomique/Laboratoire des Sciences du Climat et de l'Environnment (CEA/LSCE), France (Petoukhov *et al.*, 2000). In addition, snapshot simulations of climatic conditions at various times were undertaken with an Atmosphere-Ocean General Circulation Model (AOGCM), IPSL_CM4_D, also from

CEA/LSCE (Li, 1998; Madec *et al.*, 1999; Krinner *et al.*, submitted). Downscaling of the results obtained from these various models was undertaken using rule-based and statistical approaches, as well as by running a Regional Climate Model (MAR, see Gallée and Schayes, 1994) using boundary conditions prescribed from the AOGCM (BIOCLIM, 2004).

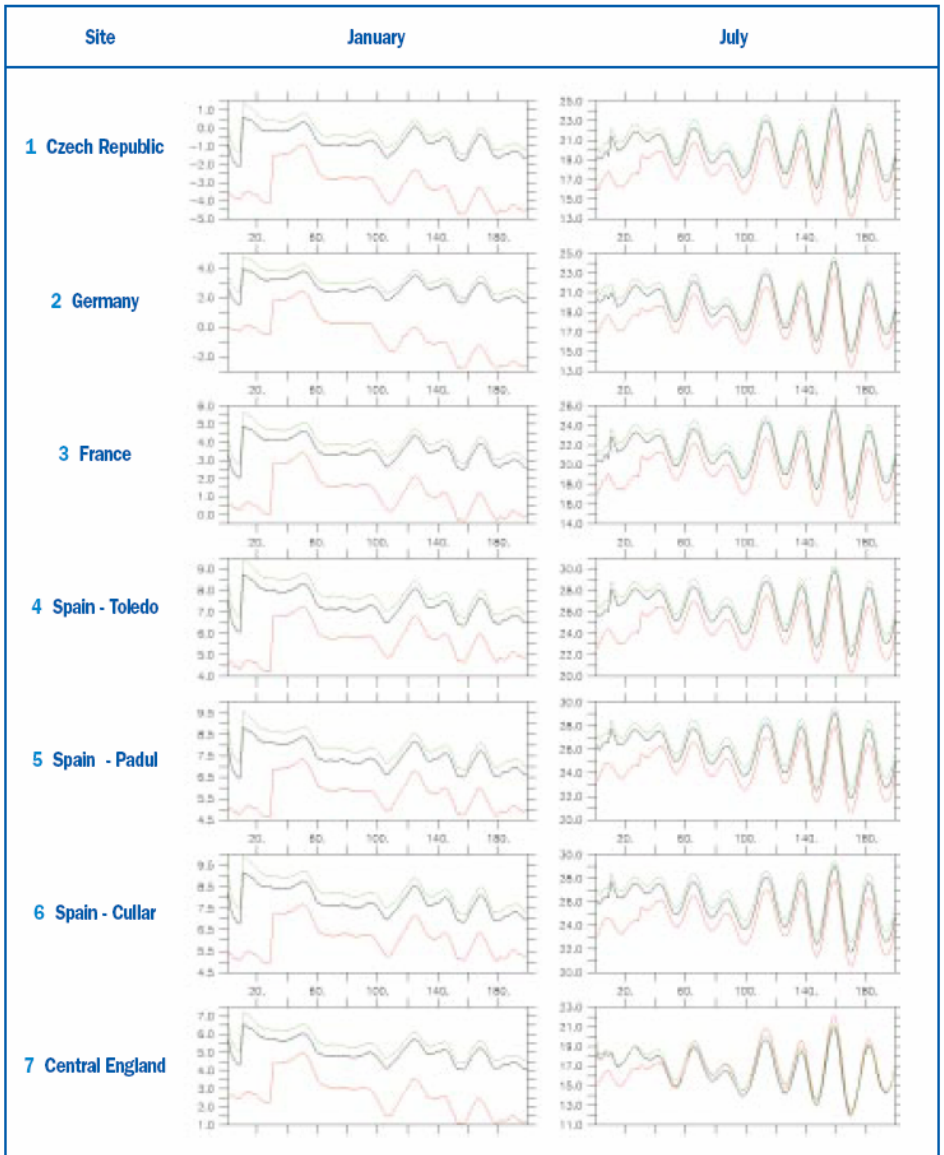

Figure 23 : *Comparison of scenarios for the next 200 kyr : temperature (°K). Natural scenario (A4a, red line); fossil fuel scenario (B3, black line); high fossil fuel scenario (B4, green line)*

Figure 3: Illustrative Climate Change Results for the next 200,000 Years (BIOCLIM, 2003)

The detailed results from these studies are all for the European region and demonstrate that the pattern of climate change follows the pattern of carbon dioxide concentration changes in the atmosphere closely, with lags measured in decades to centuries (BIOCLIM, 2004).

Overall, the studies undertaken in BIOCLIM serve to illustrate the following points of direct relevance to Yucca Mountain:

- Anthropogenically induced climate change is projected to be considerable, is likely to reach a maximum over the next few hundred years and is then likely to persist throughout the next few hundred thousand years, i.e. through to when peak doses are projected to occur at Yucca Mountain;
- The possibility of substantial anthropogenically induced climate change is taken seriously by European waste management organizations, is included by them in their research programs, and is included in assessment studies through the application of quantitative models;
- Although the global carbon cycle is not fully understood and alternative scenarios for future carbon dioxide emissions need to be considered, it is possible, with sufficient research effort, to construct an envelope of future concentrations of carbon dioxide in the atmosphere that can be used as a basis for assessment studies;
- Various EMICs are now available (see Claussen *et al.*, 2002) that allow transient projections of future global climate to be made on time scales of several hundred thousand years, these studies can be complemented with snapshot studies of key periods using AOGCMs;
- These same models have proven capable of simulating many aspects of climate change observed in the paleoclimatic record;
- Various techniques are available for downscaling EMIC and AOGCM results to smaller spatial scales.

It is further noted that transient climate modeling on long time scales is a rapidly developing field and that capabilities in this area will increase very substantially in the next few years. In particular, a wider ensemble of models is likely to become available, and the spatial and temporal resolution of those models is likely to be enhanced. Thus, no issues of principle arise in applying climate modeling to Yucca Mountain out to the time of peak dose. Specifically, there is no reason to exclude *a priori*, as EPA has done potential future anthropogenic influences on climate.

It might be argued that although the modeling of future climates is possible, it would not contribute significantly to evaluation of the safety of the facility. The basis for such an argument would be that the main concern is with increased precipitation and infiltration, and that such increases are likely to occur in glacial conditions, as these are likely to be cooler and wetter than at the present day. Although it is indeed the case that glacial conditions are likely to be cooler and wetter, those conditions do not necessarily bound conditions prejudicial to repository performance that could occur in future warm world conditions. Specifically, global warming is associated with increased evaporation and a strengthening of the hydrological cycle, with delivery of increased energy and moisture to the atmosphere. In these circumstances, substantial reorganization of atmospheric systems can occur and these have the potential to increase precipitation significantly at the site. In particular, there could be an increase in the number and intensity of storm events. The range of current climate model simulations available suggests that the Yucca Mountain region could be wetter or drier in a human-warmed world. Although it is clear that it will be hotter, there is substantial uncertainty whether it will be drier or wetter. However, if the likely increases in hurricane intensity and rainfall amounts take place due to global warming, we must consider the possibility that there will be more intense hurricanes capable of reaching Yucca Mountain. Given that Hurricane Nora reached southern Nevada in 1997, and resulted in up to 300 mm of precipitation in some Southwest U.S. locations, it is safe to say that precipitation totals of this amount, superimposed on the current range are possible. Moreover, if there is an anthropogenically induced increase in mean precipitation during the hurricane season, the number could be larger, as the largest rainfall events in the Southwest U.S. tend to be those associated with coincident/colliding tropical and frontal storms. Furthermore, hurricane-related rainfall is intense and concentrated in just a couple days of rainfall at any location. As noted above, the susceptibility of arid environments to event-driven infiltration and the highly non-linear relationships involved mean that such events may have a disproportionate effect on infiltration and repository performance.

A further consideration relevant to the Draft EPA Rule is that uncertainties in climate projections do not increase beyond 10,000 years after present, at least in terms of the range of climate conditions that could occur, rather than their detailed timing. As illustrated in Figure 2, atmospheric carbon dioxide levels are likely to peak within the next few hundred years and the maximum of global warming is likely to occur soon after that peak. The projected peak concentration of carbon dioxide is in the range 1000 to 2000 ppm, i.e. a factor of 3.6 to 7.1 times larger than the pre-industrial concentration. In these circumstances, partial or complete removal of the Greenland ice sheet is very likely to occur (Gregory *et al.*, 2004; Houghton *et al.*, 2001), resulting in potential large-scale reorganization of the global circulation. In addition, there may be substantial changes in ice-cover in West Antarctica (Oppenheimer and Alley, 2004; Thorne *et al.*, 2000) and the possibility of a positive feedback effect due to methane release from clathrates cannot be discounted (Archer and Buffett, 2005). As ice-sheet collapse has a characteristic timescale of a few hundred to a few thousand years (Oppenheimer and Alley, 2004; Houghton *et al.*, 2001; Thorne *et al.*, 2000) and feedbacks from clathrate releases would be expected to occur on similar or shorter timescales, the next few thousand years are considered likely to be a period of unusually large changes and instabilities of climate. In contrast, beyond a few thousand years, atmospheric carbon dioxide levels are envisaged as slowly declining, but still sufficiently high that renucleation of the Greenland ice sheet is unlikely for up to 500,000 years (Archer and Ganopolski, 2005), so boundary conditions on the global climate system will change much more gradually and climatic modeling will be more readily justified. As a combination of EMICs and AOGCMs is required to model climate over the next 10,000 years and the same combination of models has to be used beyond that time, the fact that climate conditions are assessed as becoming more stable after the next few thousand years suggests that we can have more confidence in climate modeling results beyond 10,000 years than over the next few thousand years. More particularly, there is no step change in our capability to project climate change, given a particular emissions scenario, at around 10,000 years.

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Mike Thorne and Associates Limited

Michael Thorne

Qualifications PhD FSRP
Year of birth 1950
Nationality British

KEY SKILLS

- Radiological protection
- Assessing the radiological safety of disposal of radioactive wastes
- Distribution and transport of radionuclides in the environment
- Expert elicitation procedures
- Probabilistic safety studies
- Development of safety criteria
- Pharmacodynamics

CAREER HISTORY

2001- **Mike Thorne and Associates Limited**

Development of Models for Radionuclide Transfers to Sewage Sludge and for Evaluating the Radiological Impact of Sludge applied to Agricultural Land
Client – Food Standards Agency

Includes a review of literature and the development and implementation of probabilistic models for such transfers.

Development of Biokinetic Models for radionuclides in Animals
Client – Serco Assurance

Development of updated biokinetic models for use by the Food Standards Agency in their SPADE and PRISM modelling systems

Review Studies for the Proposed Australian National Radioactive Waste Repository
Client – RWE NUKEM

Reviews of reports on animal transfer factors and of the potential effects of climate change on the repository plus development of a model for the biokinetics of the ^{226}Ra decay chain in grazing animals.

Development and Application of a Model for Assessing the Radiological Impacts of ^{3}H and ^{14}C in Sewage Sludge
Client – NNC Ltd

Development of a model based on physical, chemical and biochemical principles for the uptake of 3H and 14C into sewage sludge and their subsequent distribution and transport after application of the sludge to agricultural land.

Support for development of the Drigg Post-closure Radiological Safety Assessment
Client - BNFL

Support in the areas of FEP analysis, biosphere characterisation, human intrusion assessment and the effects of natural disruptive events. In addition, provision of advice of future research initiatives that should be pursued by BNFL.

Co-ordination of biosphere research and participation in BIOCLIM
Client – UK Nirex Ltd

Co-ordination of research on climate change, ice-sheet development, near-surface hydrology and radionuclide transport, as well as participation in an international programme on the implications of climate change for radioactive waste disposal.

Review of Parameter Values
Client – AEA Technology/Serco Assurance

Review of biosphere parameter values for use in the ANDRA assessment model AQUABIOS.

Effects of Radiation on Organisms Other Than Man
Client – AEA Technology/Serco Assurance

Study for ANDRA to identify appropriate indicator organisms and develop appropriate dosimetry and effects models for those organisms.

Development of a Database related to Emergency Planning
Client – AEA Technology (Rail)

Identification of relevant international, overseas and national legislation, regulations and guidance, and production of brief summaries of the documents.

Dose Reconstruction for Workers on a Uranium Plant
Client - McMurry and Talbot

Dose reconstruction for the plaintiffs in a case relating to the Paducah Gaseous Diffusion Plant.

Dose Reconstruction for a Worker Exposed to Pu and Am
Client – Pattinson and Brewer

Dose reconstruction for a worker exposed by a puncture wound in the finger while working at a glove box.

1998-2001 **AEA Technology**

Assessment of Remediation Options for Uranium Liabilities in Eastern Europe
Client - European Commission

Studies of remediation requirements relating to mines, waste heaps and hydrometallurgical plant in Bulgaria, Slovakia and Albania.

Evaluation of Unusual Pathways for Radionuclide Transport from Nuclear Installations
Client – Environment Agency

Review of literature and conduct of formal elicitation meetings to determine potential pathways and evaluate their radiological significance.

Revision of Exemption Orders Made Under the Radioactive Substances Act
Client – DETR

Review of requirements for revision and preparation of a draft text for the purposes of consultation.

Support Studies on the Drigg Post-closure Performance Assessment
Client - BNFL

Support in the areas of FEP analysis, biosphere characterisation, human intrusion assessment and the effects of natural disruptive events. In addition, provision of advice of future research initiatives that should be pursued by BNFL.

Development of Models for the Biokinetics of H-3, C-14 and S-35 in Farm Animals
Client - FSA

Review of relevant literature, development of appropriate biokinetic models and implementation in stand-alone software.

Integration of Aerial and Ground-based Monitoring in the Event of a Nuclear Accident
Client - FSA

Desk-based review and simulation study designed to determine optimum monitoring strategies for different types of accidents.

Elicitation of Parameter Values for use in Radiological Impact Assessment Models
Client - FSA

Expert elicitation study to provide distributions of parameter values for use in the suite of assessment models currently used by the FSA for routine and accidental releases.

Biosphere Research Co-ordination and Assessment Studies
Client - United Kingdom Nirex Ltd

Continuation of a programme of work originally undertaken at Electrowatt Engineering (UK) Ltd

Site Investigation and Risk Assessment - Hilsea Lines
Client - Portsmouth City Council

Radiological assessment of a radium-contaminated site.

1987-1998 **Electrowatt Engineering (UK) Ltd**

Evaluation of Inhalation Doses from Uranium
Client - Baron & Budd

Provision of expert witness support in a class action relating to environmental exposure from a uranium plant.

Biosphere Studies Relating to Drigg
Client - BNFL

Provision of advice on time-dependent biosphere modelling for the Drigg low-level radioactive waste disposal facility.

Development of a Siting Policy for Nuclear Installations: Harbinger Project and Follow-up Study
Client - HSE/NSD

Review of existing policy and development of alternatives as a precursor to application to a wide range of installations, not restricted to commercial reactors.

Support to the Rock Characterisation Facility Public Enquiry
Client - UK Nirex Ltd

Preparation of position papers and rebuttals of evidence.

Radiation Doses to an Individual as a Consequence of Working on the San Onofre Nuclear Power Plant
Client - Howarth & Smith

Interpretation of personal and area monitoring data for legal purposes.

Interpretation of Uranium in Urine Data for the Fernald, Ohio Feed Materials Processing Center
Client - Institute for Energy and Environmental Research

Interpretation of urinalysis and lung counting data, and appearance as an expert witness in the associated trial.

Determination of Failure Probabilities for use in PRA
Client - Nuclear Installations Inspectorate

Development of new approaches to the use of Bayes Theorem in defining component failure probabilities for use in PRA when statistics on actual failures are limited.

Review of Inventory Information
Client - UK Nirex Ltd

Review of uncertainties in inventories of individual radionuclides.

ALARP Study of Options for the Treatment, Packaging, Transport and Disposal of Plutonium Contaminated Material
Client - UK Nirex Ltd

Use of multi-attribute utility analysis to establish which option is preferred.

Expert Judgement Estimation of Intrusion Model Parameters
Client - British Nuclear Fuels plc

Project Manager of a study assessing the risks of human intrusion into Drigg radioactive disposal site using expert judgement techniques.

Brainstorming Study of Risks Associated with Building Structures
Client - Building Research Establishment

Participation in a classification study of the health risks associated with buildings including both injuries and disease.

Rongelap Resettlement Project
Client - Marshall Islands Government

Participation in an oversight committee evaluating the radiological safety of Rongelap in the context of resettlement by its evacuated community.

Radiological Consequences of Deferred Decommissioning of Hunterston A
Client - Scottish Nuclear Ltd

Project Manager of a study of the radiological impacts of groundwater transport of radionuclides, releases to atmosphere and intrusion.

Reviews of Safety Documentation
Client - UK Nirex Ltd

Review of safety related documentation for Packaging and Transport Branch.

The Sheltering Effectiveness of Buildings in Hong Kong
Client - Ove Arup & Partners

Project Manager of a study evaluating the shielding effectiveness of all types of building in Hong Kong for volume sources of photons in air and surface deposition sources.

Assessment of the Radiological Impact of Releases of Radionuclides from Premises other than Licensed Nuclear Sites
Client - Ministry of Agriculture, Fisheries and Food

Project Manager of a study to identify representative premises, obtain data on their releases of radionuclides and assess radiological impacts using a new methodology developed for the project.

Assessment of the Radiological Implications of Uranium and its Radioactive Daughters in Foodstuffs
Client - Ministry of Agriculture, Fisheries and Food

Project Manager of a review study of concentrations of uranium and its daughters in foodstuffs, taking local and regional variations in uranium concentrations in soils, sediments and waters into account.

Radionuclides in Sewage
Client - Her Majesty's Inspectorate of Pollution

Project Manager of a study including a desk review on alternative methods of disposal of sewage sludges, interpretation of monitoring data relating to radionuclide discharges from Amersham International to the public sewer system, development of a model for radionuclide transport in sewers, and collection and analysis of effluent, foul water, sediment, sludge and other samples suitable for use in model validation studies.

Accident Consequence Calculations
Client - Nuclear Installations Inspectorate

Project Manager of a study to assess the radiological consequences of various atmospheric releases using the MARC code.

Definition of Threshold Recording Levels for Drums of ILW
Client - UK Nirex Ltd

Project Manager of a study of the implications of post-closure radiological impacts of radioactive waste disposal in defining Threshold Recording Levels for radionuclides in individual waste drums.

Definition of Expert Judgment Exercises Relating to Nuclear Safety
Client - Commission of the European Communities

Project Manager for a study defining expert judgment exercises relating to conceptualisation, representation and input data specification. Included a comprehensive review of available formal expert judgment procedures, and mathematical and behavioural aggregation techniques.

Definition of Research Requirements Relating to the Use of Expert Judgment in Parameter Value Elicitation for Reactor Safety Studies in a UK Context
Client - Nuclear Safety Research Management Unit, HSE

Development of proposals for using combined behavioural and mathematical aggregation procedures in formal elicitations of expert judgment.

Development Priorities for the Drigg Technical Development Programme
Client - British Nuclear Fuels plc

Provision of detailed advice to BNFL on future design options, and research and development priorities, in relation to radioactive waste disposal at Drigg.

Channel Tunnel Safety Studies
Client - Channel Tunnel Safety Authority

Provision of advice and guidance on safety criteria appropriate to the Fixed Link, on the classes of Dangerous Goods that may properly be carried and on the overall characteristics of the proposed Safety Case.

Development of Societal Risk Criteria
Client - Marathon Oil

Interpretation of F-N curves in the context of the offshore oil/gas industry, taking risk aversion into account.

Impacts of Salt Dispersal on Plant Communities
Client - Sir William Halcrow

Evaluation of salt dispersal from a major road in winter in relation to adjacent Sites of Special Scientific Interest.

Offsite Consequence Assessments
Client - Nuclear Electric

Studies of the offsite radiological impacts of atmospheric and liquid releases of radioactive materials from Magnox stations.

Dry Run 3
Client - Her Majesty's Inspectorate of Pollution

Uncertainty and bias studies involving formal expert judgment procedures to develop a conceptual model of those factors and interrelationships which are of significance in determining the post-closure radiological impact of a deep geological repository for radioactive wastes. This project also included advice on data and models to be used for post-closure radiological assessments.

Radiological Assessments of Drigg
Client - British Nuclear Fuels plc

Project Manager for post-closure radiological impact assessments of the Drigg LLW disposal site. Also included specification and development of computer codes relating to the radiological impact of fires, releases of radioactive gases produced by microbial action and metal corrosion, and human intrusion.

Biosphere Co-ordination
Client - UK Nirex Ltd

Co-ordination of the UK Nirex Ltd Biosphere Research Programme from its inception, including requirements definition, technical management of all projects and QA surveillance as the Client's Representative.

Biosphere Support for the Nirex Disposal Safety Assessment Team
Client - AEA Technology

Development of approaches for assessing the radiological impact of releases of radionuclides to the biosphere, plus advice on radiological protection criteria, definition of individual risk, implications of conventionally toxic chemicals in wastes and a variety of other matters.

Evaluation and Radiological Assessment of Liquid Effluent Releases from Various Premises
Client - Her Majesty's Inspectorate of Pollution

Reviews of monitoring data and evaluations of radiological impact, primarily related to Harwell, Aldermaston, Capenhurst and Amersham International.

Evaluation of the Radiological Impact of Overseas Nuclear Accidents
Client - Her Majesty's Inspectorate of Pollution

Studies of the impact of potential overseas nuclear accidents on the UK, with emphasis on survey and monitoring requirements, and the selection of appropriate radiation detection equipment for monitoring.

Bilsthorpe Power Station
Client - British Coal/East Midlands Electricity

Preparation of an Environmental Statement with emphasis on atmospheric dispersion of SO_2 and NO_x.

Gas Generation in Radioactive Waste Disposal Facilities
Client - AEA Technology

Development of a coupled microbial degradation and corrosion model for gas generation in repositories for LLW and ILW.

Effects of Chernobyl on Drinking Water Supplies
Client - Her Majesty's Inspectorate of Pollution

Evaluation of the radiological implications of enhanced concentrations of radionuclides in water supplies in England and Wales subsequent to the Chernobyl accident.

Sea Disposal of Radioactive Wastes
Client - UK Nirex Ltd

Participation in an Environmental Impact Assessment of the proposed resumption of sea-dumping of radioactive wastes.

UK Research Related to Radioactive Waste Management
Client - Her Majesty's Inspectorate of Pollution

Identification of gaps in the UK national research effort related to radioactive waste management.

Research Requirements for Repository Design and Site Investigations
Client - UK Nirex Ltd

Review of research requirements for repository design and site investigations in relation to LLW and ILW disposal in near-surface and deep repositories.

1985 - 1986 **International Commission on Radiological Protection, Sutton, Surrey, England**

Scientific Secretary responsible for arranging and minuting meetings, administrative arrangements, technical review of reports, editing of the Commission's journal, liaison with other international organisations and public relations.

1979 - 1985 **ANS Consultants Ltd, Epsom, Surrey, England**

Reviews of data on the distribution at transport of radionuclides in terrestrial and aquatic ecosystems (see publications list).

Development of a dynamic model for radionuclide transport in agricultural ecosystems and implementation of the model on various microcomputer systems.

Photon and neutron shielding studies of radiochemical plant, together with area classification and ALARA studies.

A review of UK use of the criticality code MONK and other approaches to criticality safety assessment.

Radiological and conventional safety aspects of Magnox reactor decommissioning.

Development of metabolic models for inclusion in ICRP Publication 30.

Development of pharmacodynamic models for toxic chemicals.

Review of neutron activation analysis in studies of radionuclide transport in soils and plants.

Experimental studies on radionuclide transport in soils and plants using various photon-emitting radionuclides.

Support for DoE work on probabilistic risk assessment of LLW and ILW disposal.

Review of UK research requirements for HLW disposal.

Post-closure radiological impact assessment of the proposed LLW and ILW facility at Elstow, Bedfordshire.

Development of a generalised biosphere model for use in probabilistic risk assessments of solid radioactive waste disposal.

Initial development of a mathematical model for use in assessing the radiological impact of contaminated groundwater.

Development, computer implementation and comprehensive documentation of a model to calculate the radiological impact of intrusion into radioactive waste repositories.

Development of a general-purpose computer code for solving first-order differential equations using a hybrid Predictor-Corrector/Runge-Kutta method.

Studies on the potential radiological consequences of Magnox reactor accidents.

1974 - 1979 **Medical Research Council Radiobiology Unit, Chilton, Didcot, Oxon, England**

Development of dosimetric and metabolic models for use in ICRP Publication 30.

Studies on the metabolism of plutonium in bone and relationships to blood flow.

Theoretical studies on radionuclide metabolism and dosimetry.

Development of techniques in neutron-induced autoradiography and alpha imaging.

Image analysis studies of plutonium in bone, uranium in lungs, lysosomal inclusions in cells and heterochromatin.

Studies on the clearance of inhaled UO_2.

Alpha spectroscopy in support of toxicity studies with Ra-224.

Data analysis in connection with experimental animal studies on the potential efficacy of neutron therapy using 42 MeV neutrons.

1971 - 1974 **University of Sheffield**

Experimental studies on the reaction $\gamma + p \rightarrow \pi^0 + p$ at photon energies between 1 and 3 GeV, using a linearly polarised photon beam.

PROFESSIONAL ACTIVITIES AND MEMBERSHIP

- Fellow of the Society for Radiological Protection and Immediate Past President
- Member of the Eco-ethics International Union
- Visiting Fellow at the Climatic Research Unit, University of East Anglia

SELECTION OF PUBLICATIONS

A measurement of the beam asymmetry parameter for neutral pion photoproduction in the energy range 1.2 - 2.8 GeV. P.J.Bussey, C. Raine, J.G. Rutherglen, P.S.L. Booth, L. Carroll, G.R. Court, A.W. Edwards, R. Gamet, C.J. Hardwick, P.J. Hayman, J.R. Holt, J.N. Jackson, J. Norem, W.H. Range, F.H. Combley, W. Galbraith, V.H. Rajaratnam, C. Sutton and M.C. Thorne. London Conference (1974) Abstract 997.

The measurement of the polarisation parameters S, P and T for positive pion photoproduction between 500 and 1700 MeV. P.J. Bussey, C. Raine, J.G. Rutherglen, P.S.L. Booth, L.J. Carroll, P.R. Daniel, C.J. Hardwick, J.R. Holt, J.N. Jackson, J.H. Norem, W.H. Range, F.H. Combley, W. Galbraith, V.H. Rajaratnam, C. Sutton, M.C. Thorne and P. Waller. Nuclear Physics, B104, (1976) 253-276.

The polarised beam asymmetry in photoproduction of eta mesons from protons 2.5 GeV and 3.0 GeV. P.J. Bussey, C. Raine, J.G. Rutherglen, P.S.L. Booth, L.J. Carroll, P.R. Daniel, A.W. Edwards, C.J. Hardwick, J.R. Holt, J.N. Jackson, J. Norem, W.H. Range, W. Galbraith, V.H. Rajaratnam, C. Sutton, M.C. Thorne and P. Waller. Physics Letters, 61B, (1976) 479-482.

Aspects of the dosimetry of plutonium in bone. M.C. Thorne. Nature, 259, (1976) 539-541.

The toxicity of Sr-90, Ra-226 and Pu-239. M.C. Thorne and J. Vennart. Nature 263, (1976) 555-558.

Radiation dose to mouse testes from Pu-239. D. Green, G.R. Howells, E.H. Humphreys and J. Vennart with Appendix by M.C. Thorne. Published in "The Health Effects of Plutonium and Radium", Ed. W.S.S. Jee, (J.W. Press, Salt Lake City, Utah, 1976).

The distribution and clearance of inhaled uranium dioxide particles in the repository tract of the rat. Donna J. Gore and M.C. Thorne. In "Inhaled particles IV", Ed. W.H. Walton, (Pergamon Press, Oxford, 1977) pp. 275-284.

Theoretical aspects of the distribution and retention of radionuclides in biological systems. M.C. Thorne. J. Theor. Biol., 65, (1977) 743-754.

Aspects of the dosimetry of emitting radionuclides in bone with particular emphasis on Ra-226 and Pu-239. M.C. Thorne. Phys. Med. Biol., 22, (1977) 36-46.

A new method for the accurate localisation of Pu-239 in bone. D. Green, G. Howells and M.C. Thorne. Phys. Med. Biol., 22, (1977) 284-297.

The measurement of blood flow in mouse femur and its correlation with Pu-239 deposition. E.R. Humphreys, G. Fisher and M.C. Thorne. Calcif. Tiss. Res., 23, (1977) 141-145.

The distribution of plutonium-239 in the skeleton of the mouse. D. Green, G.R. Howells, M.C. Thorne and J. Vennart. In "Proceedings of the IVth International Congress of the International Radiation Protection Association Vol. 2 (Paris 1977).

The visualisation of fissionable radionuclides in rat lung using neutron induced autoradiography. D.J. Gore, M.C. Thorne and R.H. Watts. Phys. Med. Biol., 23 (1978) 149-153.

Lymphoid tumours and leukaemia induced in mice by bone-seeking radionuclides. J.F. Loutit and T.E.F. Carr with an appendix by M.C. Thorne. Int. J. Radiat. Biol., 33, (1978) 245-263.

Plutonium-239 deposition in the skeleton of the mouse. D. Green, G.R. Howells and M.C. Thorne. Int. J. Radiat. Biol., 34, (1978) 27-36.

Imaging of tissue sections on Lexan by alpha-particles and thermal neutrons; an aid in fissionable radionuclide distribution studies. D. Green, G.R. Howells, M.C. Thorne and R.H. Watts. Int. J. Appl. Radiat. Isotopes, 29, 285-295 (1978).

Analytical techniques for the analysis of multi-compartment systems. M.C. Thorne. Phys. Med. Biol., 24, 815-817 (1979).

The initial deposition and redistribution of Pu-239 in the mouse skeleton: implications for rodent studies in Pu-239 toxicology. D. Green, G.R. Howells and M.C. Thorne. Br. J. Radiol., 52, 426-427 (1979).

Bran and experimental colon cancer. M.C. Thorne. Lancet, ii, 13 January 1979, p.108.

Quantitative microscopic studies of the distribution and retention of Pu-239 in the ilium of the female CBA mouse. D. Green, G.R. Howells and M.C. Thorne. Int. J. Radiat. Biol., 36, 499-511 (1979).

Techniques for studying the distribution of alpha emitting and fissionable radionuclides in histological lung sections. T. Jenner and M.C. Thorne. Phys. Med. Biol., 25, 357-364 (1980).

Morphometric studies of mouse bone using a computer-based image analysis system. D. Green, G.R. Howells and M.C. Thorne. J. Microscopy, 122, 49-58 (1981).

A semi-automated technique for assessing the microdistribution of ^{239}Pu deposited in bone. D. Green, G.R. Howells and M.C. Thorne. Phys. Med. Biol., 26, 379-387 (1981).

Radionuclide distribution and transport in terrestial and aquatic ecosystems, Volumes 1 to 6. P.J. Coughtrey, M.C. Thorne et al. A.A. Balkema, Rotterdam 1983-1985.

Dynamic models for radionuclide transport in soils, plants and domestic animals. M. C. Thorne and P. J. Coughtrey. In: Ecological Aspects of Radionuclide Release (Ed. P. J. Coughtrey). British Ecological Society Special Publication No. 3, Blackwell, Oxford, 1983.

Studies on the mobility of radioisotopes of Ce, Te, Ru, Sr and Cs in soils and plants. P.J. Coughtrey, M.C. Thorne, D. Jackson and G.F. Meekings. In: CEC Symposium on the Transfer of Radioactive Materials in the Terrestial Environment Subsequent to an Accidental Release to Atmosphere. Dublin, April 1983.

A study of the sensitivity of a dynamic soil-plant-animal model to changes in selected parameter values. M.C. Thorne, P.J. Coughtrey and G.F. Meekings. In: CEC Symposium on the Transfer of Radioactive Materials in the Terrestial Environment Subsequent to an Accidental Release to Atmosphere. Dublin, April 1983.

Microdosimetry of bone: implications in radiological protection. M.C. Thorne. In: Metals in Bone, N.D. Priest (Ed.) MTP Press, Lancaster (1985), pp. 249-268.

Non-stochastic effects resulting from internal emitters: dosimetric considerations. M.C. Thorne. J. Soc. Rad. Prot., 6 (1986).

Pharmacodynamic models of selected toxic chemicals in man. Vol. 1. Review of metabolic data. M.C. Thorne, D. Jackson and A.D. Smith. MTP Press, Lancaster, 1986.

Pharmacodynamic models of selected toxic chemicals in man. Vol. 2. Routes of intake and implementation of pharmacodynamic models. A.D. Smith and M.C. Thorne. MTP Press. Lancaster 1986.

Generalised computer routines for the simulation of linear multi-compartment systems. D.Jackson, A.D. Smith, M.C. Thorne and P.J. Coughtrey. Environmental Software, 2 (1987), 94-102.

The demonstration of a proposed methodology for the verification and validation of near field models. J-M. Laurens and M.C. Thorne. In: Proceedings of an NEA Workshop "Near-field Assessment of Repositories for Low and Medium Level Radioactive Waste". pp. 297-310. NEA/OECD, Paris, 1987.

Principles of the International Commission on Radiological Protection System of Dose Limitation. Br. J. Radiol., 60 (1987), 32-38.

The origins and work of the International Commission on Radiological Protection. H. Smith and M.C. Thorne. Invest. Radiol., 22 (1987), 918-921.

The potential for irradiation of the lens and cataract induction by incorporated alpha-emitting radionuclides. D.M. Taylor and M.C. Thorne. Health Phys., 54 (1988), 171- 179.

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Implications of environmental change for biosphere modelling: work for UK Nirex Ltd. M.C. Thorne. Proceedings of an International Symposium on Safety Assessment of Radioactive Waste Repositories. OECD Paris (1990), 860-865.

The Biosphere: Current Status, December 1989. NSS/G114. M.C. Thorne. Available from UK Nirex Ltd, Curie Avenue, Harwell, 1990.

The Nirex Overview. M.C. Thorne and D. George. In: Future Climate Change and Radioactive Waste Disposal: Proceedings of an International Workshop. C.M. Goodess and J.P. Palutikof (Eds). NSS/R257. Available from UK Nirex Ltd, Curie Avenue, Harwell, 1991.

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The estimation of failure rates for low probability events, M M R Williams and M C Thorne, Progress in Nuclear Energy, 31 (1997), 373-476.

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A Guide to the Use and Technical Basis of the Gas Evolution Program MICROX: A Coupled Model of Cellulosic Waste Degradation and Metal Corrosion, R Colosante, J E Pearson, S Y R Pugh, A Van Santen, R G Gregory, M C Thorne, M M R Williams and R S Billington, Nirex Safety Studies Report NSS/R167, July 1997.

UK Nirex approach to the protection of the natural environment, M J Egan, M C Thorne and M A Broderick, Stockholm Symposium.

Post-closure performance assessment: treatment of the biosphere, M A Broderick, M J Egan, M C Thorne and J A Williams, Winnipeg Symposium.

The application of constraint curves in limiting risk, M C Thorne, J. Radiol. Prot., Vol. 17, 275-280, 1997.

The biosphere in post-closure radiological safety assessments of solid radioactive waste disposal, M C Thorne, Interdisciplinary Science Reviews, Vol. 23, 258-268, 1998.

An illustrative comparison of the event-size distributions for γ-rays and α-particles in the whole mammalian cell nucleus, K Baverstock and M C Thorne, Int. J. Radiat. Biol., 74, 799-804, 1998.

Southport '99, Achievements and Challenges: Advancing Radiation Protection into the 21st Century, Proceedings of an International Symposium, M C Thorne (Ed.) Society for Radiological Protection, London, 1999.

Modelling radionuclide distribution and transport in the environment, K M Thiessen, M C Thorne, P R Maul, G Prohl and H S Wheater, Environmental Pollution, 100, 151-177, 1999.

Use of a systematic approach for the Drigg post-closure radiological safety assessment, G Thomson, M Egan, P Kane, M Thorne, L Clements and P Humphreys, DisTec 2000, Disposal Technologies and Concepts 2000, Kontec Gesellschaft für technische Kommunication mbH, Tarpenring 6, D-22419, Hamburg, 413-417, 2000.

Validation of a physically based catchment model for application in post-closure radiological safety assessments of deep geological repositories for solid radioactive wastes, M C Thorne, P Degnan, J Ewen and G Parkin, Journal of Radiological Protection, 20(4), 403-421, 2000.

An approach to multi-attribute utility analysis under parametric uncertainty, M Kelly and M C Thorne, Annals of Nuclear Energy, 28, 875-893, 2001.

Radiobiological theory and radiation protection, M C Thorne, British Nuclear Energy Society International Conference on Radiation Dose Management in the Nuclear Industry, May 2001.

Development of a solution method for the differential equations arising in the biosphere module of the BNFL suite of codes MONDRIAN, M M R Williams, M C Thorne, J G Thomson and A Paulley, Annals of Nuclear Energy, 29, 1019-1039, 2002.

A model for evaluating radiological impacts on organisms other than man for use in post-closure assessments of geological repositories for radioactive wastes, M C Thorne, M Kelly, J H Rees, P Sànchez-Friera and M Calvez, J. Radiol. Prot., **22**, 249-277, 2002.

Background Radiation: Natural and Man-made, M C Thorne, BNES 4th International Conference on Health Eeffects of Low-level Radiation, 22-24 September 2002, Keble College, Oxford, UK, CD Available from BNES.

Background Radiation: Natural and Man Made, M C Thorne, Journal of Radiological Protection, 23, 29-42, 2003.

Comments from the Society for Radiological Protection on ICRP Reference 02/305/02 – Protection of Non-Human Species From Ionising Radiation, M C Thorne, Journal of Radiological Protection, 23, 107-115, 2003.

Estimation of animal transfer factors for radioactive isotopes of iodine, technetium, selenium and uranium, M C Thorne, J. Environ. Radioact., In the press.

BIOGRAPHICAL SKETCH

JONATHAN OVERPECK

EDUCATION

Ph.D. Geological Sciences, Brown University, RI, 1985
M.S. Geological Sciences, Brown University, RI, 1981
AB Geology (Honors), Hamilton College, Clinton, NY, 1979

PROFESSIONAL AND ACADEMIC EXPERIENCE

Director, Institute For The Study of Planet Earth, Univ. of Arizona, Tucson, 1999-present
Professor, Dept. of Geosciences, Univ. of Arizona, Tucson, 1999-present
Adj. Assoc. Professor, Dept. of Geological Sciences, University of Colorado, 1992-2001
Fellow, Institute for Arctic and Alpine Research, Univ. of Colorado, 1992-1999
Director, World Data Center-A for Paleoclimatogy, Boulder, CO, 1992-1999
Head, NOAA Paleoclimatology Program, Nat. Geophysical Data Center, Boulder, 1991-1999
Associate Research Scientist, Lamont-Doherty Geological Observatory, 1986-1990
Post-doctoral Res. Scientist, Lamont-Doherty Geological Observatory, 1985-1986

RESEARCH INTERESTS

My research focuses on using climate and ecosystem records of the past ca. 200,000 years, along with an array of environmental modeling strategies, to understand recent environmental change, and also to constrain what might happen in the next 100 to 200 years. I maintain active paleoenvironmental data generation and modeling labs, and have active field and analysis programs on four continents – mostly focused on those parts of the climate system that are most important to decision-makers in society (e.g., El Niño Southern Oscillation, monsoons and Arctic variability). I have a special interest in "abrupt climate change" (including western North American megadrought, and sea level), particularly of interglacial climates, and have been involved in National Research Council studies related to this issue. Abrupt non-linear change is perhaps the biggest wildcard in the climate change debate. My students and I are also using data and models to understand climate-induced vegetation change, past, present and future, and are particularly interested in implications for future biodiversity conservation. Since coming to the University of Arizona, I have become heavily involved building university-stakeholder partnerships, and in the development of improved scientific decision-support for stakeholders in society.

SELECTED PUBLICATIONS (from over 80 total)

Overpeck, J.T., C. Whitlock, and B. Huntley. 2003. Terrestrial biosphere dynamics in the climate system: past and future. Pages 81-103 in K. Alverson, R. Bradley and T. Pedersen, eds., *Paleoclimate, Global Change and the Future* (IGBP Synthesis Volume).

National Research Council. 2002. *Abrupt Climate Change: Inevitable Surprises.* National Academy Press, Washington, D.C. 182 pp., (Overpeck is a co-author).

Cole, J.E., J.T. Overpeck, and E.R. Cook. 2002. Multiyear La Niña events and persistent drought in the contiguous United States. *Geophysical Research Letters* 29, 10.1029/2001GL013561

Urban, F.E., J.E. Cole, and J.T. Overpeck. 2000. Influence of mean climate change on variability in a 155-year tropical Pacific coral record. *Nature* 407:989-993.

Overpeck, J.T., and R.S. Webb. 2000. Non-glacial rapid climate events: past and future. *Proceedings of the National Academy of Sciences* 97:1335-1338.

ACTIVITIES AND ACCOMPLISHMENTS

HONORS

Sigma Xi, 1979; Hamilton College Senior Fellow, 1978-1979; US Dept. of Commerce Unusually Outstanding Performance Award, 1991; Dept. of Commerce Bronze Medal, 1994; Nat. Geophysical Data Center Director Award, 1995; Dept. of Commerce Gold Medal, 1998; American Meteorological Society's Walter Orr Roberts Award, 2001.

SYNERGISTIC ACTIVITIES

Lead Presenter (Paleoclimate), United Nations Intergovenmental Panel on Climate Change (IPCC) 4th Assessment Scoping Meeting, April 2002 (Morocco).

Member, NOAA Regional Integrated Sciences and Assessments Executive Committee, 2003-present

Co-chair, Science and Technology Working Group, Planned University of Arizona/City of Tucson ca. $60M Science Center," 2002-present.

Chair, NSF Arctic System Science (ARCSS) Committee, 2002-present. Leading the planning and execution of a integrated arctic system synthesis, as well as development of new science plan for the ARCSS Program.

Co-convener, CLIVAR/PAGES/IPCC Workshop "A multi-millennia perspective on drought and implications for the future" Tucson, AZ November, 2003.

Member, NOAA Climate and Global Change Working Group – serves as a primary mechanism for advice to NOAA on climate and global change matters, 2003-present

Member, National Academy of Sciences/NRC Committee (and workshop co-organizer) on "Coping with Increasing Demands on Government Data Centers, 2002-2003

Member, National Academy of Sciences/NRC Committee (and workshop co-organizer) on "Abrupt Climate Change: Science and Policy" 2001-2002.

Co-Chair, IGBP PAGES-WCRP CLIVAR Working Group, 1995-present

Member, American Meteorological Society Board on Higher Education, 2002-2005

Member, U.S. National Research Council National Committee for International Quaternary Association (INQUA), 1997-2003

COLLABORATORS

David Anderson, NOAA, Roger Bales, UA, Warren Beck, UA, Bonnie Colby, UA, Julie Cole, UA, Andrew Comrie, UA, Tim Finan, UA, Konrad Hughen, Woods Hole Oceanographic, Malcolm Hughes, UA, Jeff Kiehl, National center for Atmospheric Research, Steve Jackson, U. of Wyoming, John King, U. of Rhode Island, Christian Koeberl, U. of Vienna, Scott Lehman, U. of Colorado, Maria-Carmen Lemos, U. of Michigan, Diana Liverman, UA, Kam-biu Liu, Louisiana State U., Barbara Morehouse, UA, Dan Osgood, UA, Bette Otto-Bleisner, National Center for Atmospheric Research, Larry Peterson, U. of Miami, Chris Scholz, Syracuse U., Robert Schowengerdt, UA, Soroosh Sorooshian, UA, John Southon, U. of California, Irvine, Tom Swetnam, UA

GRADUATE STUDENTS AND POSTDOCTORAL RESEARCHERS

Graduate students: M.S.: Alex Robertson, Frank Urban (co-advisor), Kathy Likos, Allison Drake (current) Ph.D.: Mike Kerwin, Konrad Hughen, Jennifer Mengan (co-advisor), Carrie Morrill (co-advisor), Tim Shanahan (current), Jessica Conroy (current).

Post-docs: Elsa Cortijo, Teri King, Connie Woodhouse, Nan Schmidt (current).

TOTAL SINCE 1973

4 M.S. students; 6 PhD students; 4 Postdoctoral researchers
5 male, 9 female; 13 US citizens, 1 foreign nationals

GRADUATE ADVISOR

Thompson Webb III, Brown University

POSTGRADUATE ADVISORS

William Ruddiman (Columbia University), James Hansen (NASA Goddard Institute for Space Studies)

ACACIA

A Consortium for the Application of Climate Impact Assessments

Tom M.L. Wigley

Date and place of birth

18 January 1940; Adelaide, South Australia

Academic Record:

1959	B.Sc. (University of Adelaide) Major subjects: Pure Mathematics III (Distinction), Applied Mathematics III (Distinction), Physics III (Credit)
1960	B.Sc. Hons (University of Adelaide) Mathematical Physics (IIA)
1961-2	Commonwealth Bureau of Meteorology Training Course (standing: first)
1967	Ph.D. (University of Adelaide) (Mathematical Physics: Dissertation entitled 'Problems in Plasma Dynamics and Fluid Mechanics')

Awards:

1991 Member, Academia Europaea

1992 Sixth Annual Climate Institute Award

1993 *Who's Who in the World*, Eleventh Edition, 1993/1994

1997 Outstanding Scientific Paper Award, National Oceanic and Atmospheric Administration, Environmental Research Laboratories

1998 Norbert Gerbier - MUMM International Award for the paper entitled "A search for human influences on the thermal structure of the atmosphere" by B.D. Santer et al., published in *Nature*, Vol. 382, July 1996

Biographical details:

Tom Wigley was born and educated in Australia. His undergraduate (honours) degree was in Mathematical Physics, completing three majors (Pure Mathematics, Applied Mathematics and Physics) instead of the normal two. He then trained as a meteorologist at the Bureau of Meteorology Training School (a 15-month course), subsequently working for a year as a research meteorologist before returning to university to do a Ph.D. His doctoral dissertation in the Department of Mathematical Physics, University of Adelaide, dealt with the kinetic theory of plasmas.

After graduating in 1967, he joined the faculty of the Mechanical Engineering Department at the University of Waterloo, Ontario, Canada where he stayed until 1975. Here he taught courses in applied mathematics, statistics, air pollution and meteorology. Apart from completing some work in plasma physics while on leave at the U.K. Atomic Energy Authority in Culham, U.K. during 1969, his main research interests during this period were in air pollution and aqueous geochemistry. The former included important work of the dynamics and dispersion of industrial plumes (particularly moist plumes), while the latter produced highly cited papers on the dissolution kinetics of calcite, chemical modelling and carbon isotope geochemistry.

In 1975, he moved to the U.K. to take up a "soft money" research job in climatology, in the then fledgling Climatic Research Unit in the School of Environmental Sciences at the University of East Anglia, Norwich, U.K. In 1978, on the retirement of Professor H.H. Lamb, he became Director of the Unit. Since then, the Unit has become firmly established as one of the world's leading centres in climatology. In 1993, he resigned as Director of the Climatic Research Unit to take up the position of Director of the Office for Interdisciplinary Earth Studies at the University Corporation for Atmospheric Research, Boulder, CO. He was appointed as an NCAR/UCAR Senior Scientist in 1994.

Wigley has published in diverse aspects of the broad field of climatology; from data analysis, to climate impacts on agriculture and water resources, to climate, sea level and carbon cycle modelling, to paleoclimatology. He has concentrated recently on facets of the greenhouse problem, and contributed as a lead author in each of the six recent major reviews of this problem (US DOE, WMO/UNEP/ICSU-SCOPE, and the 1990, 1992, 1994 and 1995 IPCC Reviews). He is one of the most highly cited scientists in the discipline.

Appointments:

1962-3	Meteorologist, Research Section, Commonwealth Bureau of Meteorology, Melbourne, Australia
1968-72	Assistant Professor, Department of Mechanical Engineering, University of Waterloo, Ontario, Canada
April-December 1969	Vacation Associate, United Kingdom Atomic Energy Authority, Culham Laboratory, Abingdon, Berks, U.K. (on study leave from University of Waterloo)
1972-75	Associate Professor, Department of Mechanical Engineering, University of Waterloo, Ontario, Canada
September 1972-April 1973	Visiting Fellow, Research School of Pacific Studies, Australian National University, Canberra, Australia (on study leave from University of Waterloo)
1975-78	Senior Research Associate, Climatic Research Unit, University of East Anglia, Norwich, U.K.
1978-93	Director, Climatic Research Unit, University of East Anglia, Norwich, U.K.
Jan. 1987-	Professor (personal chair in climatology), School of Environmental Sciences, University of East Anglia
1993-1994	Director, Office for Interdisciplinary Earth Studies (OIES), University Corporation for Atmospheric Research (UCAR), Boulder, CO
July 1994-	Senior Scientist, National Center for Atmospheric Research (NCAR), Boulder, CO.

Professional Consultant for:

United States Atomic Energy Commission
Ontario Hydro-Electric Power Commission
Canada Department of the Environment
Eastman Kodak Company
Tennessee Valley Authority

United Nations Development Programme, Morocco
U.K. Overseas Development Administration
Food and Agriculture Organization of the United Nations
British Petroleum Research Centre
U.S. Environmental Protection Agency
Electric Power Research Institute
U.K. Department of the Environment
United Nations Environment Programme, Nairobi
Center for Nuclear Waste Regulatory Analyses, Southwest Research Institute
Hagler Bailly Consulting, Inc.
Lawrence Livermore National Laboratory
Science and Policy Associates, Inc.

Other Items:

(*indicates currently active)

National or International Committees

U.K. Department of the Environment Steering Group for Climatic Change
Natural Environment Research Council Stable Isotope Project Coordinating Panel
SCOR/IOC Committee on Climatic Changes and the Ocean (CCCO)
Panel on Paleoclimatology
Royal Meteorological Society Council
UNEP Correspondence Group on the Interface between Climate (Global Circulation) Models and Crop-Climate Models
Meteorology and Atmospheric Physics Subcommittee, British National Committee for Geodesy and Geophysics
International Commission on Climate of the International Association of Meteorology and Atmospheric Physics
Technical Advisory Panel, U.S. Environmental Protection Agency, Global Change Research Program
Chairman, Climate Hazards Coordination Group, Commission of the European Communities, Climatology and Natural Hazards Programme
Atmospheric Sciences Committee, Natural Environment Research Council
Forestry Research Co-ordination Committee, Review Group on Climatic Change and Forestry
Electric Power Research Institute, Global Climate Advisory Committee
Science Review Group, Hadley Centre for Climate Prediction and Research, U.K. Meteorological Office
*Electric Power Research Institute, ACACIA (A Consortium for the Application of Climate Impact Assessment) Planning Committee

*American Geophysical Union, Atmospheric Sciences Section, Climate and Paleoclimate Committee
*United Nations Environment Program (UNEP) Scientific and Technical Advisory Panel (STAP) of the Global Environment Facility (GEF)

Editorial

Editorial Board, *Climatic Change* (Kluwer Academic Publishers)
Editorial Advisory Board member, *Atmospheric Sciences Library* (Kluwer Academic Publishers)
*Editorial Board, *Mitigation and Adaptation Strategies for Global Change* (Kluwer Academic Publishers)
*Editorial Advisory Board member, *Encyclopedia of Climate & Weather* (Robert Ubell Associates)
*Editorial Board, *Global Climate Change Digest* (Elsevier Science Publishing Co., Inc.)
*Editorial Board, *Climatic Dynamics* (Springer-Verlag)
*Referee for numerous journals

Publications (1990-present)

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ACACIA Sponsors

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Page last updated: 21 May 2001

Curriculum Vitae

PROFESSOR H.S. WHEATER

Name:	Howard Simon Wheater
Date of Birth:	24.6.49
Nationality:	British
Present Appointment:	Professor of Hydrology, Department of Civil & Environmental Engineering, Imperial College, University of London Head, Environmental and Water Resource Engineering Section, Department of Civil & Environmental Engineering, Imperial College Chairman, Centre for Environmental Control and Waste Management, Imperial College Director, MSc in Hydrology for Environmental Management, Imperial College

Degrees:

B.A.	(1st Class Honours) Engineering Science University of Cambridge	1971
M.A.	University of Cambridge	1974
Ph.D.	University of Bristol	1977

Awards:

Rolls-Royce Industrial Scholarship	1968
Entrance Exhibition, Queens' College, Cambridge	1968
Senior Scholarship, Queens' College, Cambridge	1971
Institution of Civil Engineers Overseas Premium	1984
British Hydrological Society President's Prize	1996

Membership of Professional Bodies and Learned Societies:

Fellow, Royal Academy of Engineering (FREng)	2003
Life Member, International Water Academy (Oslo)	1999
Fellow, Institution of Civil Engineers (C.Eng, FICE) (Member 1978)	1999
Member, British Hydrological Society (MBHS)	1983
Fellow, Royal Meteorological Society (F.Roy.Met.Soc)	1985
Member, American Geophysical Union	1983

Appointments:

1978-	**Imperial College of Science, Technology & Medicine**
1993-	Professor of Hydrology
1990-1993	Reader in Engineering Hydrology, Department of Civil Engineering
1987-1990	Senior Lecturer in Engineering Hydrology, Department of Civil Engineering
1978-1987	Lecturer in Engineering Hydrology, Department of Civil Engineering
1972-1978	**University of Bristol, Department of Civil Engineering**
1976-1978	Research Associate Integration of tidal power within the UK electricity generating network (SERC).
1975-1976	Research Assistant Regional analysis of rainfall-runoff relations. Effects of urbanization on flood runoff (Water Research Centre).

1972-1975 Research Assistant
Research into catchment hydrology, physical simulation of hydrological processes, rainfall-runoff simulation techniques for flood management.

1968-1972 **Rolls-Royce Ltd (Aero Engine Division).** Engineering apprenticeship
Fluid Mechanics research.

July 1978 to date Present Appointment

Teaching:

Lecturer to Engineering Hydrology MSc/DIC Course
Lecturer to Environmental Engineering MSc/DIC Course
Lecturer to Environmental Technology MSc/DIC Course
Lecturer to Environmental Diagnosis MSc/DIC Course
Current courses include: Urban Hydrology; Evaporation & Soil Water Processes; Catchment Hydrology; Irrigation
Lecturer to Civil Engineering and Civil and Environmental Engineering, MEng
Courses include: Environmental Engineering, Water Resources

Current Research Group:

8 research students.
5 research assistants.

Current Research Grants & Contracts:

Radionuclide transport in vegetated soils
UK Nirex 1988-2003, £2.8 million
National Infrastructure for Catchment Hydrology Experiments (NICHE)/Lowland Catchment Research (LOCAR)
Joint Infrastructure Fund 1999-2004, £2 million
Hydrogeochemical functioning of lowland permeable catchments: from process understanding to environmental management
NERC/Environment Agency 2002-2005, £500k
Generation of spatially-consistent rainfall data,
DEFRA 2003-2006, £680K

Research training: 32 Ph.D students, 80 MSc projects (past and present).

College Administration: Department of Civil & Environmental Engineering
Head, Water and Environmental Engineering Teaching Division,
Head, Environmental & Water Resource Engineering Section,
Chairman, Departmental Research Committee
Chairman, Centre for Environmental Control and Waste Management
Director, Engineering Hydrology MSc/DIC Course (1984-date)
Member, College ENTRUST Panel

Learned Society Activities, UK and International Scientific Administration:

British Hydrological Society
President 1999-2001
Chairman, Southern Section, 1984-96
Chairman, Research Sub-Committee, 1994-
Chairman, Scientific Programme Committee, Intnl Conf on Hydrology in a Changing Environment, Exeter, 1998
Natural Environment Research Council
Chairman, Land & Water Resources Review Panel, Centre for Ecology and Hydrology, 1996-
Chairman, LOCAR Working Group, 1998-9
Member, Freshwater Sciences Research Grants & Training Awards Committee, 1993-7
Member, HYREX Programme Committee, 1992-6

Member, Environmental Diagnostics Programme Committee, 1995-
Member, LOCAR Programme Committee, 1999-
MAFF Committee
Member, Flood Estimation Handbook Committee, 1994-1999
Environment Agency Flood Warning and Management
R&D Advisory Group, 1999-
DEFRA/EA Broad Scale Modelling Thematic Advisory Group 2000-
Chairman, UNEP-UK Working Group on Protection of the Supply and Quality of Freshwater (1991 Rio Summit prepcon)
Member, UNESCO Panel on Arid Zone Water Resource Development, 1995-
1993-97 Scientific Advisor to the Ministry of Foreign Affairs, Republic of Hungary with respect to the Gabcikovo-Nagymaros Barrage System (GNBS) case and Counsel and Advocate for Hungary, at the International Court of Justice, The Hague.

Editorial Activities:

Editor, Progress in Environmental Science, 1998-2001
Reviewer for: Proc. Roy. Soc., Water Resources Research, J. Hydrology, J. Hydrological Processes, Proc. Instn. Civil Engrs., Hydr. Sci. Jnl., etc.

External Examining & Assessment:

Referee: Stockholm Water Prize
Professorial Appointments: Elector, University of Cambridge; University of Tufts, USA
Academic Appointments/Promotions: University of Edinburgh, University of Khartoum, University of Jordan, University of Riyadh, Institute of Hydrology
DSc: University of Bristol
PhD: Universities of Bradford, Bristol, Birmingham, Lancaster, London, Reading, Salford, Southampton, Woollangong (Australia)
Research Grant Assessment: NERC, EPSRC, MAFF, British Council, Leverhulme Foundation, Royal Society, NOAA (USA), Swiss National Science Foundation, etc.

Overseas Development:

Overseas lecture courses given include:-

1979-1984	University College, Galway, Eire, International Hydrology MSc course
1982	University of Dar-es-Salaam, ANSTI/UNESCO International Hydrology MSc
1984	Catholic University of Chile, Santiago, Hydrology short course
1986	CETESB, Sao Paulo, Brazil, Hydrology & Water Quality short course
1990	Tsinghua University, Beijing, China, Water Quality lectures
1998	UNESCO Workshop, Amman, Jordan, Wadi Hydrology.

Recent Invited Lectures:

UNESCO Arab Region, IHP Workshops, Beirut (1999); American Geophysical Union Fall Meeting, San Francisco (1999); Intnl Water & Energy Conference, Las Vegas (2000); Intnl Arid Zone Hydrology Conference, Cairo (2000); Starker Lecturer, Oregon State University (2000); American Geophysical Union Fall Meeting, San Francisco (2002); Kyoto Water Summit (2003).

Principal Areas of Expertise:

Unsaturated zone and groundwater hydrology
Extensive research is being undertaken into modelling of unsaturated flow and solute transport, and the soil-plant-atmosphere continuum. A major (15 year) research contract with UK Nirex Ltd. involves lysimeter experiments of radionuclide transport in soils and vegetation uptake, and the integrated modelling

of these processes for safety assessment of radioactive waste management. 1, 2 and 3D models have been developed; current research is focussing on redox-dependent geochemical interactions and the representation of uncertainty.

A major (£10million) national initiative (LOCAR) has been developed to study lowland permeable catchments, including a £2million infrastructure grant to Imperial College. Three catchments have been instrumented in detail to monitor hydrological fluxes and water quality, including special instrumentation to investigate aquifer properties and stream-aquifer interactions. See also surface water quality, below.

Research in groundwater contaminant transport has included numerical methods for advectively-dominated contaminant transport, field and modelling studies of saline intrusion, field and laboratory studies of non-aqueous phase liquids in groundwater, laboratory and numerical modelling of microbial de-nitrification processes, and modelling of chemically-reactive contaminant transport. A recent EPSRC/BG project has investiged microbial degradation of organic pollutants at a Gas works site and developing models for coupled flow, transport, geochemical interactions and microbial degradation. Other research is developing a framework for uncertainty analysis for well protection zones and investigating the value of data in risk reduction.

Groundwater recharge studies include UK applications and research into surface water/groundwater interactions in ephemeral flow systems, in Saudi Arabia, Oman, Botswana and the USA.

Recent consultancy includes advice to British Nuclear Fuels Ltd. on hydrological, hydrogeological and groundwater modelling studies at the Drigg nuclear repository, Cumbria and a study of Karst groundwater flooding in the Irish Republic.

Arid zone hydrology and water resource development
Major projects include:- Northern Oman Flood Study (1981) (Principal Investigator) and Five Wadis Study, S.W. Saudi Arabia (1985-88) (Senior Expert) in addition to numerous smaller-scale flood and water resource studies in the Middle East and Africa (Yemen, Jordan, Oman, UAE, Botswana). Published research includes rainfall analysis and simulation, rainfall-runoff modelling, groundwater recharge. Current research includes sustainable development of alluvial groundwater (Botswana), stochastic spatial-temporal rainfall modelling and rainfall-runoff processes (Arizona), NASA-funded University of Arizona real-time hydrological modelling project.

Rainfall modelling
Stochastic models of rainfall have been developed for various applications with support from NERC and DEFRA . Poisson-process based single site models have been developed for UK and US applications, and are currently being extended for regional UK application in conjunction with continuous simulation rainfall-runoff modelling for flood design and management. A suite of models for spatial rainfall analysis and spatial-temporal simulation has been developed, ranging from radar-based continuous space-continuous time methods to Generalised Linear Modelling of daily rainfall including both temporal and spatial non-stationarity. Applications include modelling impacts of climate variability on flooding in W. Ireland and next-generation rainfall-runoff modelling for UK flood practice.

Rainfall-runoff modelling, flood hydrology and urban hydrology
Major flood investigations have been carried out for the Water Research Centre, Severn-Trent Water, Thames Water, the Basque Regional Government, the Oman Government and numerous consultants. Recent UK studies have focussed on urbanisation effects, with respect to a new town development in Hampshire. New point and spatial rainfall modelling methods are being

developed for continuous simulation modelling with NERC and MAFF support. A new suite of rainfall-runoff modelling software has been developed with NERC support for regionalisation of rainfall-runoff models, with application to the UK, USA and Southern Africa. A recent study of Karst flooding problems in W. Ireland has included analysis of non-stationarity in rainfall (Southern Water, on behalf of Irish Govt.). Prof. Wheater is currently developing a national programme of research on land use impacts on flooding as part of a £5million EPSRC research programme.

Surface water quality
Current research funded by NERC and the Environment Agency of England and Wales is focussing on the development of decision support models of nutrients for lowland catchment management, including diffuse and point source loads and in-stream processes. A recent EU contract has developed modelling systems for nutrient response of the Wash catchments in Eastern England, as a pre-pilot study for the EU Water Framework Directive. Research into hydrology and water quality in upland Britain has addressed surface water acidification (Royal Society funding (in collaboration with Norwegian and Swedish Academies of Science) and NERC (Environmental Diagnostics) support). Published research includes field process and model identification studies. Water quality research overseas has included development of integrated river and lake water quality models for decision support for pollution control (EU, in collaboration with Tsinghua University, Beijing and Suez Lyonnaise-des-Eaux).

Large-scale hydrological modelling
Research into improved hydrological modelling for global climate models has included new methods for disaggregation of spatial rainfall and evaluation of SVAT schemes at point and catchment scale, contributing to the NERC TIGER programme and the GCIP study of the Mississippi. Current research in collaboration with the Hadley Centre is focussing on improved modelling of climate change impacts over the Nile.

International Consultancies & Research Contracts:
Royal Oman Police & Diwan of HM Sultan Qaboos of Oman; Ministry of Agriculture & Water, Riyadh (as consultant to Dames & Moore); Royal Commission of Jubail, Saudi Arabia; Dar Al Handasah (flood protection of Medinah & Mecca); Howard Humphries (UAE); Balfour Beatty International (Sri Lanka); Maunsells (Oman); Zambian Cons. Copper Mines; CETESB, Sao Paulo (Brazil); Basque Regional Government (Spain); Dar Al Handasah (Yemen); Shimizu Corporation (Japan); European Community (Nepal); JCE (Jordan); Travers Morgan (Oman); Government of Hungary; Southern Water Global (Eire); DANIDA (Botswana), European Union (China), UNESCO.

UK Consultancies and Research Contracts:
Anglian Water Authority, Severn Trent Water Authority, Thames Water Authority, Royal Society, UK Nirex Ltd., British Nuclear Fuels Ltd., Balfours, W.S. Atkins, Watson Hawksley, Hydro-logic Ltd., Electrowatt, Her Majesty's Inspectorate of Pollution, Eagle Star Property Management, Natural Environment Research Council, Binnie and Partners, Thames Water Utilities Ltd, EPSRC, Halcrow, Environment Agency, Department of Environment, Food and Rural Affairs.

Appendix F

INSTITUTE FOR ENERGY AND ENVIRONMENTAL RESEARCH

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http://www.ieer.org

Bad to the Bone:

Analysis of the Federal Maximum Contaminant Levels for Plutonium-239 and Other Alpha-Emitting Transuranic Radionuclides in Drinking Water

Arjun Makhijani, Ph.D.

Institute for Energy and Environmental Research

June 2005

Table of Contents

Acknowledgements

I would like to thank the reviewers, Mike Thorne, Geoff Fettus, and Beatrice Brailsford, for their help in commenting on various stages of this report. Mike Thorne commented on every draft and reviewed all the calculations. His extensive knowledge of the history of how radiation protection science has evolved since the issuance of the International Commission on Radiological Protection's Publication Number 2 was indispensable to ensuring that the complexity of the issues involved are fully reflected in the analysis. I am grateful to my colleague, Annie Makhijani, who did some of the preliminary research and calculations. Sriram Gopal did some early calculations as well, when he was a staff scientist at IEER. He is now a law student. Brice Smith and Lisa Ledwidge served as internal reviewers and Lois Chalmers helped with the bibliographic research and the references, including getting the various editions of the safe drinking water regulations that were essential for doing the research.

This study is part of IEER's technical support project for grassroots groups on nuclear weapons related issues in the United States. We gratefully acknowledge the generous support of John Merck Fund, Ploughshares Fund, Public Welfare Foundation, Stewart R. Mott Charitable Trust, Town Creek Foundation, Colombe Foundation, Education Foundation of America, Ford Foundation, New Cycle Foundation, and the New-Land Foundation, as well as the individual donors who give generous support to our work.

Arjun Makhijani
Takoma Park, Maryland
June 2005

Main findings

The limit for gross-alpha contamination of drinking water is based on science that is over four decades old. It is an unsatisfactory basis for public health protection that is at variance with the content and intent of the safe drinking water regulations for radionuclides that were first promulgated in 1976. Specifically, the scientific understanding of how plutonium and other alpha-emitting, long-lived transuranic radionuclides behave in the human body, and of the magnitude of radiation dose they deliver to various organs, has changed a great deal, beginning with revisions first published by the International Commission on Radiological Protection in the late 1970s. The United States Environmental Protection Agency (EPA) first officially adopted these changes for assessment of radiation doses in its Federal Guidance Report 11, published in 1988. More changes have occurred since that time, which allow estimation of doses to people of various ages including infants.

EPA last reviewed its radionuclide standards in the year 2000 as part of a legally-mandated process. But despite the fact that it had been more than a decade since the publication of Federal Guidance Report 11, the EPA chose not to revise the maximum contaminant levels (MCLs) for alpha-emitting, long-lived transuranic radionuclides in that review. The next scheduled review of radionuclide MCLs in drinking water will occur in 2006.

This report provides an analysis of the changes in the dose estimates to the maximally exposed organ that have occurred since the MCL limits for radionuclides were first set in 1976. It presents the scientific underpinning for tightening the MCL for alpha-emitting, long-lived transuranic radionuclides by a factor of one hundred compared to the present gross alpha MCL of 15 picocuries per liter (pCi/L).

1. Drinking water maximum contaminant limits for plutonium-239 and other alpha-emitting, long-lived transuranic radionuclides are about a hundred times too lax.

The most recent science, as published by the EPA, indicates that the radiation dose to the most exposed organ, the surface of the bone, from drinking water contaminated to the maximum allowable limit is about a hundred times greater than the dose to what in 1976 was regarded as the maximally exposed organ (the marrow-free skeleton). This indicates that the drinking water standards are about a hundred times too lax, as measured by the intent of the regulations when they were first promulgated. The current MCL for each alpha-emitting, long-lived transuranic radionuclide separately is 15 picocuries per liter.

2. Drinking water regulations – when they were first set - explicitly included military sources of radionuclides – specifically, fallout from testing.

3. A much tighter MCL for alpha-emitting, long-lived transuranic radionuclides is needed to prevent lax approaches to cleanup of weapons sites.

Once drinking water is polluted to a few picocuries per liter, which is many times the indicated MCL by current science, it will be essentially impossible to remediate it. A stringent MCL is therefore needed as a guide to the United States Department of Energy (DOE) in its cleanup and as a preventive measure for protecting public water supplies.

4. The vast majority of public water systems will incur no costs from the proposed change and a few would incur a one-time monitoring cost.

Since the vast majority of public water systems have alpha-emitting, long-lived transuranic radionuclide levels orders of magnitude below the proposed MCLs (from weapons testing). They are not at risk for further contamination. No sampling, monitoring, or remediation is needed for these systems.

For public water systems that are hydrologically or hydrogeologically connected to DOE sites, where large amounts of plutonium waste were dumped or were disposed of, a one-time initial sampling and analysis should be done. If found clean, further sampling need not be conducted provided the DOE maintains a thorough water sampling program for surface and ground waters on site and reports the results publicly. It is presently mandated to do that, so no additional expenses would be incurred in this regard.

5. The relaxation of DOE goals in regard to cleanup and the lack of national cleanup standards necessitates an urgent revision of MCLs for alpha-emitting, long-lived transuranic radionuclides, if critical drinking water systems are to be protected for the long-term.

The timing and urgency of the main recommendation of this report, that MCLs for alpha-emitting, long-lived transuranic radionuclides be tightened by one hundred times (see below), derives largely from the very large inventories of alpha-emitting, long-lived transuranic radionuclides at several (DOE) nuclear weapons sites. Some wastes containing these radionuclides (both low-level and transuranic wastes) were dumped in unlined trenches in cardboard boxes and similar non-durable packaging in the early decades of the Cold War. The primary sites are in Idaho, Nevada, New Mexico, South Carolina, Tennessee, and Washington state. Further, the combined plutonium-238, -239, and -240 inventory contained in DOE high-level waste tanks at Savannah River Site is over a million curies. In 2004, Congress gave DOE the latitude to reclassify some of this waste. DOE can now grout high-level waste in place by reclassifying it as waste incidental to reprocessing. Congress set no limit on the total residual radioactivity content of the grouted waste. Since grouting is essentially irreversible, it is imperative the DOE implement the law in a manner that is compatible with the protection of the Savannah River, which is increasingly used by more people as a source of drinking water in South Carolina and Georgia.

Recommendations

The EPA is going to review the radionuclide standards for drinking water as part of a scheduled process in 2006. We urge the EPA to revise the drinking water regulations in regard to alpha-emitting, long-lived transuranic radionuclides. The Department of Energy should evaluate its cleanup and decommissioning efforts with a view to meeting the tighter standard.

1. The EPA should reduce its maximum contaminant levels for all alpha-emitting, long-lived transuranic radionuclides, combined, by one hundred times to an MCL of 0.15 picocuries per liter during its 2006 review of radionuclide standards for drinking water.

EPA should set a combined maximum contaminant level for alpha-emitting, long-lived transuranic radionuclides of 0.15 picocuries per liter. If only one of the radionuclides in question were present, then the limit for that radionuclide would be 0.15 picocuries per liter. The radionuclides included are: neptunium-237, plutonium-238, plutonium-239, plutonium-240, plutonium-242, americium-241, and americium-243. These changes should be made as part of the EPA's review of radionuclide standards in drinking water that is scheduled for 2006.

2. The DOE should fund a one-time baseline sampling and analysis for public water systems that are hydrologically or hydrogeologically connected to DOE sites with major plutonium wastes or dumps.

DOE sites with wastes buried underground or in tanks containing more than 100 curies of alpha-emitting, long-lived transuranic radionuclides should be considered to have potential risks to drinking water. These sites include the Savannah River Site, Hanford, Idaho National Laboratory, Los Alamos National Laboratory, Oak Ridge, and the Nevada Test Site. Testing of downstream water for the purpose of providing a baseline level of contamination is desirable and should be funded by the DOE since the tiny amounts of alpha-emitting, long-lived transuranic radionuclides in current water supplies are due to military-related atomic energy activities (fallout from testing).

3. The DOE should evaluate its on-site water monitoring from the point of view of the proposed standard and intensify it, if necessary. Resources for independent verification should be provided by the federal government.

The DOE currently carries out extensive surface and ground water monitoring. This may be sufficient for the purposes of providing assurance that downstream water resources continue to be protected from contamination with alpha-emitting, long-lived transuranic radionuclides. If not, the existing programs should be intensified.

The federal government should also provide states and public water system authorities that are hydrologically or hydrogeologically contiguous to DOE sites with the funds to conduct independent checks on DOE's on-site and off-site water monitoring. Such funds would better be provided through the EPA, rather than through the DOE, in order to assure the independence of the monitoring and the continuity of the funding.

4. A separate limit of detection of each alpha-emitting, long-lived transuranic radionuclide of 0.01 picocuries per liter should be set.

5. The DOE should make public the source code for the model that is used to assess the impact of residual radioactivity on food, water, and the environment.

Argonne National Laboratory developed a "family" of programs to assess the radiological impact of environmental contamination by radionuclides. The main one, called simply RESRAD, is used to assess the impact of residual radioactivity in the soil on human beings, by estimating radiation doses by a variety of pathways, such as food and water and re-suspended soil. Its source code is not public. It does not incorporate dose conversion factors for children, infants, or fetuses at various times in their development. Its internal structure and its effects on the resulting estimates of doses and risks are not available for independent scrutiny. We strongly recommend that the RESRAD source code be made public, so that it can be examined and improved in the manner of the operating system Linux. The government, of course, need not adopt any changes that are made by the public unless it finds them useful for implementing environmental regulations. But there is no reason for holding a source code paid for by taxpayer dollars secret, particularly as billions of dollars are being spent on cleanup decisions based on the results generated by the RESRAD program.

I. Introduction

The National Primary Drinking Water Regulations specify rules that will protect drinking water and will maintain it in a state that is safe to drink. In these regulations, 40 CFR 141.66 sets safe drinking water standards for radionuclides in public water supplies under the Safe Drinking Water Act.[1] These standards are set in two ways: by specifying maximum contaminant levels of drinking water or by specifying maximum allowable dose to the whole body or any organ as a result of ingestion of drinking water. However, as demonstrated below, the concentration limits currently in effect for alpha-emitting transuranic radionuclides in drinking water are grossly inadequate to protect public health. Achievement of reductions in concentration is necessary to protect public health.

The current maximum contaminant level (MCL) as set forth in 40 CFR 141.66(c) for gross alpha particle activity, including radium-226, but excluding uranium and radon, is 15 picocuries per liter. There is a sub-limit for radium-226 and radium-228, combined, of 5 picocuries per liter (including any naturally present radium-226 and radium-228). For instance, if water is contaminated with plutonium-239 alone, the level of contamination could reach as high as 15 picocuries per liter if no other qualifying alpha-emitting radionuclides were present. If radium-226 is present to the maximum allowable limit of 5 picocuries per liter,[2] then the rule allows a maximum contaminant level for gross alpha of 10 picocuries per liter. For instance, if plutonium-239 were the only alpha-emitting, long-lived transuranic radionuclide present, the MCL for plutonium-239 in this case would be 10 to 15 picocuries per liter, depending on the concentration of radium-226.

This standard was set in 1976, based on scientific assessments done in the late 1950s by the International Commission on Radiological Protection (ICRP) and the National Committee on Radiation Protection and Measurements (NCRP), a United States agency, and published as ICRP Publication 2 and in abbreviated form in the U.S. by the National Bureau of Standards as NBS Handbook 69.[3]

But the science has changed since then. As a result of these changes, as well as changes in the dose conversion factors adopted by the EPA since that time, dose estimates to the most exposed organ, while complex to assess, are far greater than those implied by the limit of 10 to 15 picocuries per liter when evaluated according to the methods specified in NBS 69.

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[1] The text now published under 40 CFR 141.66 were formerly published under 40 CFR 141.15 and 141.16. (CFR = Code of Federal Regulations). See also SDWA.

[2] This assumes that no radium-228 is present. The radium MCL in the rule is set for the combined concentration of Ra-226 and Ra-228. The former is an alpha-emitter and the latter is a beta-emitter. Hence the latter is omitted from the gross alpha part of the rule.

[3] ICRP-2, 1959 & NBS 69. NBS 69, which also bears the series title NCRP Report No. 22, is a recommendation of the National Committee on Radiation Protection and Measurements, which is now known as the National Council on Radiation Protection and Measurements (NCRP). Tables and scientific discussion are drawn from ICRP-2, 1959. NBS Handbook 69 was published in 1959 and then again, with an added table and errata, in 1963. We cite NBS 69 throughout this report. The dose conversion factors, the scientific content, and other details in NBS 69 are the same as those in ICRP 2. ICRP 2 was published by the International Commission on Radiological Protection in 1959. The NCRP was (and is) a participating organization in ICRP.

It is therefore necessary that the MCLs of transuranics in drinking water be changed in order that the MCL remain within the spirit and framework of the standards as promulgated in 1976. This can be done based on the dose conversion factors that the EPA has since adopted and published in Federal Guidance Report 11,[4] which are the basis for present EPA regulation and risk estimation. They were published in 1988. The EPA has since published Federal Guidance Report 13. This is the most recent EPA scientific publication relevant to safe drinking water standards. The scientific basis of this guidance (ICRP 72)[5] has been adopted for some federal dose calculation purposes, but not yet sanctioned for use in regard to assessing doses from drinking water. In this report, we will consider the changes in the drinking water standards for alpha-emitting, long-lived transuranic radionuclides.

The basis for the needed MCL change is the potential danger that residual radioactive pollutants remaining after cleanup of the Cold War nuclear weapons production sites will pose to individuals in this generation and future generations. Of particular concern are the long-lived transuranic radionuclides neptunium-237, plutonium-238, plutonium-239, plutonium-240, plutonium-242, americium-241, and americium-243. All of these are man-made radionuclides.

II. National Primary Drinking Water Regulations - Radionuclides

In 1959, the National Bureau of Standards published its Handbook 69 (NBS 69), which established the maximum permissible average concentrations of radionuclides in air and water calculated on the basis of a 5 rem dose to the whole body, and a 15 rem dose to the most exposed organ, also called critical organ, for each pathway and solubility class.[6] As discussed below, a somewhat different method was used for bone-seeking radionuclides like radium-226 and plutonium-239. All these limits were established for radiation workers.[7]

ICRP 2 and NBS 69 also set forth the scientific approach for calculating these maximum permissible concentrations, with ICRP 2 providing significantly greater detail. A table adding data and correcting some errors in the 1959 version of NBS 69 was published in 1963, along with the original 1959 NBS 69 publication. In the text that follows, the term NBS 69 refers to this 1963 publication, since the EPA based its drinking water standards on it.

In March 1975, the EPA proposed, for the first time, National Primary Drinking Water Regulations for public water systems.[8] The proposed rules for radionuclides were published in August of that year.[9] The regulations for contaminants other than radionuclides were promulgated in December 1975;[10] the rules for radionuclides were promulgated in July 1976.[11] The MCLs and dose limits were

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[4] FGR 11, 1988.
[5] ICRP-72, 1996.
[6] NBS 69.
[7] Until 1958 there were no separate radiation exposure limits for the public. They were the same as for workers. In 1958, the dose limits for the public were set at one-tenth the maximum allowable doses for workers (NBS 59 Addendum, page 5).
[8] Fed. Reg. 1975/03/14.
[9] Fed. Reg. 1975/08/14.
[10] Fed. Reg. 1975/12/24.
[11] Fed. Reg. 1976.

originally codified in 40 CFR 141.15 and 40 CFR 141.16, both of which have since been renumbered and consolidated, without change, into 40 CFR 141.66.[12]

In the final rule of July 1976, the EPA promulgated Maximum Contaminant Levels (MCLs) for radionuclides in public water systems either by directly specifying the MCL values (in picocuries per liter) or by specifying dose limits, which implied MCLs for drinking water, based on an adult water intake of two liters per day. The science underlying the standards was published in NBS 69. The drinking water limit for alpha-emitting radionuclides excluding uranium and radon, but including radium-226, was set at 15 picocuries per liter. There was a separate sub-limit for radium-226 and radium-228 of 5 picocuries per liter. For beta and photon-emitters the dose limit was 4 millirem per year (mrem/year) to the most exposed organ. (For radionuclides that are approximately uniformly distributed in the body, such as cesium-137 and tritium, the most exposed organ is considered to be the whole body.) The MCLs for beta- and photon-emitters were set according to the 4 mrem/year criterion, with a slight variation from this being adopted for tritium and for strontium-90. The limits for these categories have remained the same since that time.[13] Detection limits and analytical methods for radionuclides were set forth in 40 CFR 141.25.

The rule as originally promulgated discusses natural and man-made radionuclides separately. However, it does not explicitly discuss the alpha-emitting transuranic radionuclides that are the subject of this report, but specifies only a gross alpha MCL. The gross alpha limit excludes only uranium and radon and it automatically includes the alpha-emitting, long-lived transuranic radionuclides of concern here, as these radionuclides are explicitly listed in the tables in NBS 69.

The following statement indicates the intent of the regulation that first established maximum contaminant limits for man-made radionuclides in drinking water:

> Man-made radioactivity may enter the public water systems from a variety of sources. Such contamination is usually confined to systems utilizing surface waters. Past deposition of fallout materials from nuclear weapons tests, particularly strontium-90 and tritium, is probably the most important source of contamination. The dose equivalent to individual users of public water systems in some areas of the United States from this pathway is in the range of 1 to 2 millirem (mrem) per year. At present, the dose equivalent from public water systems contaminated by effluents produced in the nuclear fuel cycle is probably only a fraction of that due to fallout materials, though perhaps ranging up to 0.5 mrem per year. The dose equivalent from effluents released by medical, scientific, and industrial users of radioactive materials that enter the public water systems has not been fully quantified. Taken as a whole these users handle much smaller amounts of radioactivity than nuclear power facilities but (with the exception of tritium) their liquid releases and the resultant doses to man may be somewhat comparable.
>
> EPA recognizes that the national use of radionuclides in medicine and industry and the utilization of nuclear power to supply energy needs will unavoidably lead to some radioactivity entering the aquatic environment so that the quality of some surface waters is likely to decrease *slightly* in the future. *Even though the increase of radioactivity in drinking-*

[12] The changed numbering can be found in the 2004 edition of 40 CFR 141.

[13] The limits were first specified in 40 CFR 141.15 and 40 CFR 141.16. An MCL for uranium of 30 micrograms per liter was established on December 7, 2000, in 40 CFR 141.66 (e), based mainly on the heavy metal toxicity of uranium to the kidney. The revision to 40 CFR 141 was announced in Fed. Reg. 2000.

water will normally be small, the Agency believes that the risk of future contamination warrants vigilance. It is the intent of the proposed monitoring and compliance requirements to provide a mechanism whereby the supplier of water can be cognizant of changes in the level of radioactivity in its water sources, so that the appropriate remedial measures may be taken.[14]

While this passage does not explicitly mention nuclear-weapons-related activities and facilities, their inclusion is clearly indicated, notably from the fact that fallout from nuclear weapons testing is discussed as the most important source of surface water contamination. It is also clear from the discussion of fallout that the intent was to consider the most important sources of contamination. The mention of industrial users also does not exclude weapons facilities (which handle radioactivity in considerably smaller amounts when compared to reactor core and spent fuel inventories in the commercial nuclear power sector). It is implicit, therefore, that there was no intent to exclude alpha-emitting man-made radionuclides from the vigilance and concern of the regulations.

The understanding of what is the most exposed organ for alpha-emitting, long-lived transuranic radionuclides has evolved.

The level of doses at which concern and vigilance were warranted in regard to man-made radionuclides was a few millirem per year. The maximum contaminant level for photon- and beta-emitters was set to 4 millirem per year because they were considered to be the most important sources of man-made radioactivity:

> Considering the sum of the deposited fallout radioactivity *and additional amounts due to effluents from other sources currently in existence*, the total dose equivalent from made-made radioactivity is not likely to result in a total body or organ dose to any individual that exceeds 4 millirem per year…[15]

This quote shows that the sum of the doses from military and civilian activities was considered in evaluating the limit of 4 millirem per year that was set for beta- and photon-emitters in 1976. In fact, fallout was the single most important component of the dose from man-made radionuclides evaluated by the EPA.

The cancer fatalities from whole body exposure to 4 millirem per year from man-made beta and photon sources of radioactivity were estimated at between 0.4 and 2.0 deaths per year per million people exposed. This was comparable to the exposure to natural radium-226 and radium-228 estimated at 0.7 to 3 fatal cancers per year per million persons at the level of 5 picocuries per liter selected as the maximum contaminant level. The slightly higher fatality rate for radium (a factor of 1.2 to 1.8) at the allowable limit of 5 picocuries per liter must be seen in the context that it is a ubiquitous, naturally occurring radionuclide, with considerable variation in drinking water concentrations (which the EPA estimated at the time to be between 0.1 and 60 picocuries per liter).[16] The EPA imposed considerable costs on public water systems by requiring remediation of those systems that had levels of radium greater than 5 picocuries per liter in order to bring them to the

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[14] Fed. Reg. 1975/08/14, page 34324, emphasis added.
[15] Fed. Reg. 1975/08/14, page 34325, emphasis added.
[16] Fed. Reg. 1975/08/14, page 34325.

regulatory level. Further, the EPA mandated testing of water supplies and established detection limits (at the 95 percent confidence limit) that were considerably below the MCLs set forth in the regulation.[17] The detection limits were set in order to ensure that the mandated MCLs would not be exceeded. In considering the mandated MCLs and detection limits, the EPA took technical, health, and economic considerations into account.

In looking to the future, the EPA did not anticipate that man-made radionuclides would result in a dose of more than 4 millirem per year from drinking water, because it believed that fallout would remain the main source and that this source would decrease with time due to the ban on atmospheric tests[18]:

> The 4 millirem per year standard for man-made radioactivity was chosen on the basis of avoiding *undesirable future contamination of public water supplies as a result of controllable human activities*. Given current levels of fallout radioactivity in public water supply systems and their expected future decline, and the degree of control on effluents from the nuclear industry that will be exercised by regulatory authorities, it is not anticipated that the maximum contaminant levels for man-made radioactivity will be exceeded except in extraordinary circumstances.[19]

There is no explicit exclusion of alpha-emitting transuranic radionuclides from this statement. Also, the National Primary Drinking Water regulations explicitly mention strontium-90 in fallout. Hence, the regulations explicitly took into account a man-made radionuclide from a military activity – nuclear weapons testing – in protecting public water supplies from radioactive contaminants. Further, the critical organ listed in NBS 69 for strontium-90 and for the transuranic radionuclides that are the subject of this report was the same – the bone.

The language of the regulation indicates that the MCL in the range of 10 to 15 picocuries per liter for the alpha-emitting, long-lived transuranic radionuclides set at the time would have corresponded approximately to a bone dose of a few millirem per year according to then-prevailing estimation methods. We show in the next section, *A. Bone dose estimation in ICRP 2*, that was indeed the case. However, present-day methods result in far higher dose estimates, as discussed below in the section after next, *B. Bone dose estimation, present-day dose conversion factors*.

A. Bone dose estimation in ICRP 2

Bone dose was estimated in ICRP 2 (and NBS 69) as dose to the skeletal bone without the marrow. The reference bone-seeking radionuclide used by ICRP 2/NBS 69 was radium-226 and the reference amount was 0.1 microcurie of radium-226 in the skeletal bone. The amount of energy deposited in the bone each year corresponded to an absorbed radiation dose rate of about 3 rad per year, not accounting for relative biological effectiveness (RBE) of alpha particles. ICRP 2 used an RBE = 10, thus yielding an annual dose for a 0.1 microcurie body burden of radium-226 of 30 rem per year,

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[17] Fed. Reg. 1976, page 28404.

[18] Of the nuclear weapons states, only China was testing in the atmosphere at the time. China conducted its last atmospheric nuclear test in 1980.

[19] Fed. Reg. 1975/08/14, pages 34325-34326, emphasis added.

according to the then-prevailing method of estimation.[20] Doses were calculated by estimating a whole-body or organ burden of the radionuclide assuming lifetime ingestion or inhalation at the MCL, for which values were given either in the workplace (40-hour workweek) or continuously (168 hours per week).

Some radionuclides, such the beta-particle-emitting strontium isotopes, were recognized even then to behave somewhat differently than radium-226 in the body in that they tended to concentrate in certain parts of the bone, while radium-226 is distributed less unevenly. Research since that time has validated that observation. For instance, the alpha-emitting, long-lived transuranic radionuclides tend to concentrate adjacent to the endosteal cells on the bone surface. Hence, these radionuclides deliver a considerably higher dose to the endosteal cells than would be indicated by an assumption of uniform distribution over a marrow-free skeleton.

In order to account for non-uniform distribution of several bone-seeking radionuclides, ICRP 2 suggested (and used) a factor of safety of 5 for such radionuclides when estimating maximum permissible levels of radionuclides in air and water for workers.[21] The effect of this safety factor was to reduce the maximum allowable dose for workers from alpha-emitting, long-lived transuranic radionuclides to 6 rem per year, compared to 30 rem per year for radium-226. Correspondingly, the maximum permissible concentrations were also reduced by a factor of five.

This intent to reduce the maximum permissible dose to the bone by a factor of about 5 can be confirmed by estimating the dose corresponding to the maximum permissible burden of plutonium-239 in the bone of 0.04 microcuries specified in NBS 69. Using a value of 5.15 MeV per alpha particle and an RBE = 10, the annual dose corresponding to a bone burden of 0.04 microcuries of plutonium-239 is about 5.5 rem per year. Since the whole body and organ burdens in NBS 69 are rounded, this is in close agreement with the figure of 6 rem inferred by applying the safety factor of 5 to the radium-226 dose of 30 rem.

The MCL for soluble plutonium-239 set in NBS 69 corresponding to the 6 rem per year bone dose would be $5x10^{-5}$ μCi/cc, or $5x10^{-2}$ μCi/liter, or 50,000 pCi/liter. The current drinking water limit of 15 picocuries per liter in the absence of radium-226 corresponds to a bone dose of about 1.8 millirem per year (or 1.2 millirem per year corresponding to 10 picocuries per liter, which is the MCL for plutonium-239 in the presence of radium-226 at its MCL of 5 picocuries per liter).[22]

The bone doses corresponding to 15 picocuries per liter for various alpha-emitting, long-lived transuranic radionuclides are shown in Table 1, estimated according to the method in NBS 69 which was the prevailing scientific understanding in 1976, when the EPA first promulgated the MCLs for radionuclides. All of these calculations follow NBS 69 in assuming soluble radionuclides when estimating doses to the bone from drinking water. An assumption of soluble forms of the radionuclides is reasonable (and in keeping with the regulation as originally promulgated) since it is likely that the radionuclides will be in that form if they are present in drinking water. The presence of insoluble colloidal forms is not excluded, but the likely presence of soluble forms makes it necessary to use the uptake coefficient for that form, which has been done throughout this report.

[20] ICRP-2, 1959, page 13 and FGR 11, 1988, page 18. The current value of the RBE, often called the quality factor in the regulatory context, for alpha particles is 20.
[21] FGR 11, 1988, pages 16-19.
[22] This assumes that no Ra-228 is present.

Table 1: Bone dose from alpha-emitting, long-lived transuranic radionuclides according to NBS 69 (ICRP 2)

Radionuclide	Bone dose at 15 pCi/L in mrem/y
plutonium-238	1.8
plutonium-239	1.8
plutonium-240	1.8
americium-241	1.8
neptunium-237	3.0

Note: These doses are estimated by proportionally reducing the doses for these radionuclides corresponding to the MCLs listed in NBS 69, which correspond to a bone dose of 6 rem per year. The figure of 6 rem for bone dose for alpha-emitting, long-lived transuranic radionuclides is derived by applying the safety factor of 5 to the bone dose of 30 rem for radium-226 (see text). NBS 69 lists the kidney as well as bone as the target organs for americium-241. We consider only bone-dose-related MCLs in this report. Plutonium-242 dose is the same as plutonium-239.

The NBS 69 (ICRP 2) calculations for bone dose are not directly comparable to present-day methods of dose estimation. NBS 69 specifies annual doses to the "bone," defined as the marrow-free skeleton. But Federal Guidance Report 11, which lays out methods of dose estimation that are the basis of EPA regulations at the present time, defines committed doses to two different parts of the bone – the "red marrow" and the "bone surface."[23] The latter is defined as the most exposed organ in Federal Guidance Report 11 for alpha-emitting, long-lived transuranic radionuclides because they concentrate adjacent to the endosteal cells, which are located on the bone surface. In other words, the understanding of what is the most exposed organ for alpha-emitting, long-lived transuranic radionuclides has evolved along with the methods of dose estimation since the MCLs were promulgated in 1976.

As shown in Table 1, the range of doses to the bone using a limit of 15 picocuries per liter for alpha-emitting, long-lived transuranic radionuclides estimated according to NBS 69 is approximately from 1.8 to 3 millirem per year. This is about the same as the doses estimated from man-made radionuclides, notably in fallout, in the safe drinking water regulation as promulgated in 1976. Hence we can infer that the intent of the rule was to limit the dose from drinking water to the maximum exposed organ, defined then as the bone, to approximately 2 millirem per year.

While the bone surface was not specified as a target organ for dose calculations in 1976, when the safe drinking water regulations were promulgated, it is possible to estimate the dose to the endosteal cells at a level of drinking water contamination of 15 picocuries per liter based on the NBS 69 dose conversion factors. For plutonium-239, the annual dose to the endosteal cells would be about 26 millirem per year.[24] The bone surface dose for the other radionuclides shown in Table 1 are about the

[23] There is more recent federal guidance on the subject in *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, Federal Guidance Report No. 13. Washington, D.C., Environmental Protection Agency, 1999 (hereafter cited as FGR 13). This report also uses the same two parts of the bone as the target organs for which doses are calculated.

[24] This estimate is derived by using a mass of 120 grams for the endosteal cells corresponding to an overall skeletal mass of 7,000 grams. Further, it is assumed that one-fourth of the energy is deposited in the 120-gram mass of the endosteal cells, with the rest being deposited in other parts of the bone. This mass of the endosteal cells is specified in Federal Guidance Report 11. This gives a ratio of dose to endosteal cells of (7000/120)*0.25 = 14.6. All calculations assume that the dose to the bone permitted under NBS 69 at the specified MCL was 6 rem per year. There is some imprecision

same, except for Np-237, for which the figure is about 44 mrem per year. These estimated doses, which take into account the evolution of scientific understanding in the years after 1976, are far higher than what the safe drinking water regulations allow. The implied dose to the endosteal cells is about a factor of 14.6 higher for plutonium-239. All of these calculations were done within the framework of NBS 69, which was (and continues to be) the scientific guidance for the safe drinking water regulation.

B. Bone dose estimation, present-day dose conversion factors

Scientific understanding of radiation doses and harm from intake of radionuclides has advanced considerably over the years. Regulations have also evolved to some extent, though at a slower pace. Specifically, in the 1970s, the International Commission on Radiological Protection (ICRP) published ICRP 26 and ICRP 30 followed by ICRP 48 in 1986. The scientific work in these publications was incorporated by the EPA into Federal Guidance Report 11 in 1988. The doses from alpha-emitting, long-lived transuranic radionuclides in the new guidance issued by the EPA are much higher than those estimated by NBS 69 methods. Federal Guidance Report 11 is the report that is the basis of current EPA regulatory dose estimation methods. We will estimate bone doses according to Federal Guidance Report 11 (FGR 11) in this section. Then we discuss the same problem using Federal Guidance Report 13 (FGR 13), which is the most recent EPA Guidance, but not yet in force for regulatory calculations for doses from air and water.

1. Bone doses according to FGR 11

As touched upon above, several major changes have transpired from NBS 69 to FGR 11 so far as this analysis is concerned:

- The quality factor, or RBE, was increased from 10 to 20.
- The bone was divided into two different target organs, the “bone marrow” and the “bone surface,” as compared to a single organ, the marrow-free skeleton, in NBS 69.
- The division of the bone into two organs in FGR 11 allowed the omission of the safety factor of 5 that was used in NBS 69 to account for selective, non-uniform deposition in the bone of certain radionuclides.
- NBS 69 used annual doses, while FGR 11 provides the conversion factors for committed doses. [25]

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associated with the fact that the MCLs were rounded to one significant figure in NBS 69, but this is not significant in the present context.

[25] “Annual dose” corresponds to the amount of energy from ionizing radiation deposited in the target organ per unit mass of the organ in a single year. The dose in rem is then calculated by applying the RBE to the deposited energy. “Annual committed dose” corresponds to the amount of energy that would be deposited in the organ over the entire time that the radionuclide is present in the organ due to the intake of the radionuclide in a single year. If a radionuclide is eliminated rapidly from the body (say in a few days or weeks), as for instance is the case with tritium, then annual dose and committed dose are usually the same. But if the radionuclide is slowly eliminated from the target organ, over years or even decades (the latter is the case for alpha-emitting, long-lived transuranic radionuclides, their target organ being the bone), the dose to the bone from an intake in any given year is delivered over a period of decades after that. With the annual committed dose, the intake is over a year but the dose is delivered over a different period of time – and, in the case of alpha-emitting, long-lived transuranic radionuclides to the bone, a much longer period of time. Hence, the actual dose delivered to the person in the case of an intake of an alpha-emitting, long-lived transuranic radionuclide late in life (say a

While these technical changes are complex, it is possible to estimate the effect of the changes from NBS 69 to Federal Guidance Report 11 on doses in several different ways, each of which raises some technical issues. The approaches and issues are set forth in Table 2 using plutonium-239 as the reference alpha-TRU radionuclide.

Table 2: Approaches for deriving an updated drinking water limit for plutonium-239 that account for changes from NBS 69 to FGR 11

Approach	Issues	Derived, updated Pu-239 MCL, pCi/liter
1. Compare the NBS 69 annual bone dose to the FGR 11 bone surface annual committed dose	**Advantage**: Uses the prevailing dose framework at the time. **Disadvantages**: (i) For alpha-emitting, long-lived transuranic radionuclides, which have a long biological half-life, committed dose is not equivalent to annual dose. The actual cumulative dose over a lifetime is considerably less than the product of the years and the annual committed dose. (ii) Target organ is different – bone for NBS 69 and bone surface for FGR 11.	0.04
2. Compare NBS 69 cumulative bone dose over a lifetime at 15 pCi/L to actual cumulative bone surface dose estimated from FGR 11	**Advantage**: Closest to the intent of the regulation to limit doses to the most exposed organ. **Disadvantage**: Changes the target organ from marrow-free skeleton to bone surface.	0.08
3. Compare cumulative bone surface dose imputed from NBS 69 to bone surface dose as per FGR 11	**Advantage**: Compares the same target organ. **Disadvantage**: Changes the framework from maximally exposed organ, as defined at the time by prevailing science, to comparing bone surface dose, which was not explicitly defined in NBS 69.	12

Notes: For Pu-239, it is assumed that 63 percent of the committed dose is delivered in 50 years. The values in the last two rows correspond to a 70-year intake. The estimate in Federal Guidance Report 11 for bone "surface seeking alpha-emitters" is a factor of 12, but a value for Pu-239 is not specified. We estimate the ratio of cumulative bone surface dose from FGR 11 to NBS 69 for Pu-239 is a factor of 12.3, which is about the same as the value in FGR 11. This validates the approach used for the calculations in the last row of the above table.

Of these approaches, the first one is the least persuasive scientifically because it compares cumulative annual doses to cumulative committed doses. Since plutonium is eliminated from the bone very

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few years before death) is less than the full committed dose and less than the dose that would be delivered from the same intake early in life.

slowly (with a biological lifetime of several decades), most of the dose from intakes in the last years of a 70-year reference lifetime would be delivered after the full lifetime of even a long-lived person (even if one considers a ~100 year life, for instance). Hence, only the latter two approaches are scientifically reasonable. Both yield values for MCLs for alpha-emitting, long-lived transuranic radionuclides that are far below 15 picocuries per liter. However, they yield values also an order of magnitude different from each other – 0.08 picocuries per liter and 1.2 picocuries per liter. The approach shown in the second row is the most close to the intent of the drinking water regulation because it compares cumulative dose over a lifetime to the most exposed organ as defined in 1976 (marrow-free skeleton) and the most exposed organ as currently defined (bone surface). The last approach compares dose to the same organ (bone surface), which has scientific merit. However, it is not in accord with the intent of the regulation to limit dose in that the prevailing views of the most exposed organ (marrow-free skeleton in 1976 and bone surface in 1988) are no longer being compared. Hence, the most appropriate value to use for a new standard based on Federal Guidance Report 11 would be 0.08 picocuries per liter. However, since this is no longer the most recent scientific guidance published by the EPA, this factor would also need to be considered in the review of MCLs for alpha-emitting, long-lived transuranic radionuclides when they are reviewed in 2006.

2. Bone doses according to FGR 13

The most recent regulatory guidance for estimating doses is based on dose conversion factors published in ICRP 72. These have been incorporated into Federal Guidance Report 13, including the compact disk supplement, which has dose conversion factors for various ages published in a database.[26] The dose conversion factors are age-dependent and can be used to estimate committed doses for the remainder of life from the age of intake to age 70 years. This allows the estimation of total dose over a lifetime corresponding to a water contamination at 15 picocuries per liter.

The dose conversion factors in Federal Guidance Report 13 are generally somewhat lower than those in Federal Guidance Report 11. Therefore the total dose to the bone surface using the newer dose conversion factors in Federal Guidance Report 13 is roughly a factor of two lower than that estimated using FGR 11. In addition to the change in the dose conversion factors, water intake variation with age also needs to be considered. The current drinking water MCLs are based on an adult intake of 2 liters of water per day, excluding the water content of food. However, the water intake of children is smaller and there is also some gender variation. Further, children have a greater intake of fluids, notably in the form of milk. Therefore, we have done the Federal Guidance Report 13-based dose calculation using two sets of intake rates for various ages that are published in the literature. The first set corresponds to fluid intakes, including milk. The second set includes only water intake. These assumptions about intake rates are show in Table 3 below:

[26] FGR 13, 1999 and 2002 (the latter for the CD supplement, rev.1).

Table 3: Drinking water assumptions for FGR 13 dose calculations

Age range, years	Fluid intake, including milk, liters/day (Case 1)	Water only intake, liters/day (Case 2)
0 to 4	1.3	0.7
5 to 14	1.3	0.95
15 to 70	1.95	1.65

Note: For Case 1, the main reference is ICRP 23, 1975. The fluid intake rate of 1.4 liters per day for 10 year-olds has been changed here to 1.3 liters per day for ages 0 to 14 years. For Case 2 the main reference is Smith and Jones 2003, which provides the most recent recommendations of the British National Radiological Protection Board.

When total fluid intake is considered (i.e., Case 1 above) the cumulative lifetime dose to the bone surface from plutonium-239 over a 70-year period is about 15,500 mrem. For Case 2, water intake only, the lifetime bone surface dose is about 12,000 mrem. The corresponding dose to the maximally exposed organ under NBS 69 (the marrow-free skeleton) is 126 mrem. These doses are calculated by applying dose conversion factors specified in the relevant publications to the intake of plutonium in drinking water over a 70-year period. This last figure of 126 mrem can be viewed as the intent of the original regulation in terms of the dose to the maximally exposed organ from drinking water contaminated with plutonium to the maximum allowable limit of 15 picocuries per liter. If we compare the value of 126 mrem to the dose to the maximally exposed organ as estimated by the methods specified in Federal Guidance Report 13, we find that for drinking water intakes corresponding to Case 1, the MCL of 15 picocuries per liter is about 123 times too high and for Case 2, it is about 95 times too high. Therefore the most recent science would indicate a tightening of the current MCL for plutonium-239 (15 pCi/L) by about 123 times to about 0.122 picocuries per liter in the case of fluid intake case (Case 1) and by over 95 times to about 0.157 picocuries per liter for water intake only (Case 2). The results for the other alpha-emitting, long-lived transuranic radionuclides are similar, since the dose conversion factors are quite close to those of plutonium-239, with the exception of neptunium-237, for which the dose conversion factors are about a factor of two lower.

III. Conclusions

The analysis in this report shows that the MCL for alpha-emitting, long-lived transuranic radionuclides should be tightened by about a factor of 100 – that is, it should be reduced from 15 picocuries per liter to 0.15 picocuries per liter. A combined standard for all alpha-emitting, long-lived transuranic radionuclides will simplify the rule and reduce the cost of its enforcement. Moreover, since the plutonium isotopes among these dominate the total curie content of DOE waste and since the dose conversion factors for Pu-238, Pu-239, Pu-240, Pu-242, and Am-241 are nearly the same, using Pu-239 as a reference for deriving the combined standard MCL is reasonable from a health standpoint as well as cost-effective.[27]

The MCL for alpha-emitting, long-lived transuranic radionuclides should be reduced from 15 picocuries per liter to 0.15 picocuries per liter.

In considering what should be the optimal value for a drinking water standard for alpha-emitting, long-lived transuranic radionuclides radionuclides, we have also examined the values for a plutonium-239 limit that exists in other standards. Specifically, the surface water standard of the State of Colorado is the most relevant, since that state has been host to one of the most important plutonium handling and processing facilities in the United States, namely, the Rocky Flats Plant, near Denver. The statewide standard for plutonium-239 for surface water is 0.15 picocuries per liter.[28] It is calculated on the basis of a 30-day rolling average – that is, 30 consecutive measurements are averaged; they may or may not be taken on consecutive days. Colorado's standard is based on the risk of one person in one million developing a cancer from consuming 2 liters of water per day for 30 years.[29]

The Colorado Department of Health, Water Quality Control Commission describes the background and the rationale for changing from 15 picocuries per liter to 0.15 picocuries per liter as follows:

> **Background** The Commission previously adopted a basic standard for plutonium of 15 pCi/L and had no basic standard for americium. A basic standard was considered in this hearing for americium because it is closely associated with plutonium and these two radionuclides generally occur together. The current basic standard of 15 pCi/L plutonium was calculated using methodologies in the 1976 National Interim Primary Drinking Water Regulations and was consistent with a goal of keeping exposures below 4 millirem per year. The Basis and Purpose indicated that it was necessary and important to restrict levels because of the difficulty of removing this radionuclide by conventional treatment procedures and because the potential adverse effect on human health suggests that extreme caution be exercised in its

[27] The dose conversion factor for Np-237 is lower than those of the other alpha-emitting, long-lived transuranic radionuclides by about a factor of two.

[28] Colorado Reg. 31, 2005. The State also sets standards for other radionuclides and considers different limits for different watersheds. We have not considered these issues, some of which result in more stringent and others of which result in more lax rules. We have simply used the State of Colorado's statewide surface water limit for Pu-239 as a guide for reference.

[29] CDPHE 2002.

release to State waters. Since plutonium is predominantly an alpha emitter, the basic standard was made consistent with the 15 pCi/L alpha standard....

Basis for Commission Decision Since the previous basic standard was set, several changes have occurred: 1) a new methodology for assessing carcinogens has become the standard practice, 2) new data have resulted in periodic updates to the slope factors used in this methodology, and 3) a more refined Commission policy on appropriate levels of protection for carcinogens has been developed. This latter risk-based policy also parallels a national trend towards risk-based approach to environmental cleanup standards.

The 15 pCi/L dose-based approach was calculated using a "reference-man" and considered exposure during his working life. It was an approach designed to address questions related to occupational exposure. It did not consider sex, age and organ-specific factors over a lifetime. In contrast, the new slope factor methodology, used in EPA's 1989 Risk Assessment Guidance for Superfund Sites, is more complete, more applicable to a general population and has become the standard practice for calculating risk.

The Commission adopted a basic standard of 0.15 pCi/L for plutonium and americium, calculated using a 1×10^{-6} risk level, based on residential use. This risk level is consistent with the Commission's policy for human health protection.[30]

This reasoning is based on CERCLA, the Superfund law, but is qualitatively in accord with the reasoning in this analysis. Specifically, the central scientific point of the Colorado rule is that the science has changed, indicating greater risk than previously assumed from exposure to plutonium and americium; therefore the maximum contaminant limits should be adjusted accordingly. Further, the specific value for plutonium and americium recommended in the Colorado rule is just a factor of two lower than the geometric mean of the two values in the last two rows of Table 2 above.

In view of the complexities created by the change from NBS 69 to Federal Guidance Report 13, an MCL for alpha-emitting, long-lived transuranic radionuclides of 0.15 picocuries per liter is reasonable and justifiable. The action we are recommending is consistent with the intent of the National Primary Drinking Water Regulations as originally promulgated and is directly within the framework of the regulation as promulgated then and as it stands at present.

The primacy of the health goal (rather than numerical limits) is clear from the EPA's own description of the Safe Drinking Water Act, pursuant to which the radionuclide maximum contaminant limits are set. Its fact sheet on the Act states:

US EPA sets national standards for tap water which help ensure consistent quality in our nation's water supply. US EPA prioritizes contaminants for potential regulation based on risk and how often they occur in water supplies. (To aid in this effort, certain water systems monitor for the presence of contaminants for which no national standards currently exist and collect information on their occurrence). US EPA sets a health goal based on risk (including risks to the most sensitive people, e.g., infants, children, pregnant women, the elderly, and the immuno-compromised). US EPA then sets a legal limit for the contaminant in drinking water or a required treatment technique.[31]

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[30] Colorado Reg. 31, 2005, pages 138-139.
[31] EPA 2004.

By this standard, the 15 picocuries per liter limit for transuranic radionuclides is obsolete, not protective of public health, against the spirit of the Safe Drinking Water Act, and, as shown above, not in accord with the intent of the initial regulation. Because of this, the EPA should take up consideration of a tightened standard in its upcoming 2006 drinking water radionuclide review.

The 15 pCi/L limit for transuranic radionuclides is obsolete, not protective of public health, against the spirit of the Safe Drinking Water Act, and, as shown above, not in accord with the intent of the initial regulation.

Corresponding to the change in the MCL for alpha-emitting, long-lived transuranic radionuclides, there is also a need for a change in the detection limit. Table B in 40 CFR 141.25 should be modified to include a separate detection limit of 0.01 picocuries per liter for each alpha-emitting, long-lived transuranic radionuclide. This detection limit is well within the capabilities of present-day techniques. The current detection limit for these radionuclides is 0.001 picocuries per liter, according to Argonne National Laboratory. The errors at such low levels can be large however. The error at 0.01 picocuries per liter, the recommended detection limit, is estimated by Argonne National Laboratory to be 10 percent.[32]

We recognize that alpha-emitting, long-lived transuranic radionuclides are not ubiquitous in significant concentrations, unlike naturally occurring radionuclides like radium-226, thorium-232, and thorium-230. The vast majority of public water systems can therefore be exempted from routine monitoring requirements relating to alpha-emitting, long-lived transuranic radionuclides. The monitoring requirements for these radionuclides should be applied to public water systems that draw water from aquifers or surface water that have potential hydrologic or hydrogeologic connections to areas or facilities with waste tanks, waste burial pits, and other potential sources of alpha-emitting, long-lived transuranic radionuclides in combined totals in excess of 100 curies (see below).[33] Wastes disposed of at shallow and intermediate depths are included in this definition. Alpha-emitting, long-lived transuranic radionuclides that are contained in secure buildings with institutional controls would be exempt from this limit and the associated monitoring requirements.

We recognize that the main recommendation of this report, to set a separate standard for alpha-emitting, long-lived transuranic radionuclides, requires that the present gross alpha limit be split up into two parts – one for alpha-emitting, long-lived transuranic radionuclides and the other for naturally occurring alpha-emitting radionuclides. However, this is not a departure from the content or intent of the present rule, for several reasons.

First, the present rule itself does not have a single standard for alpha-emitting radionuclides. There is a sub-limit for radium-226 and radium-228 of 5 picocuries per liter. Since radium-226 is an alpha emitter, there is in effect a separate sub-limit for an alpha emitter up to maximum of 5 picocuries per liter (depending on how much radium-228, a beta-emitter, is also present). Second, the gross alpha

[32] ANL 1995, Chapter 7, Table 7.1.

[33] For instance, the 100 curie limit is equivalent to 1,000 metric tons of transuranic waste containing alpha-emitting, long-lived transuranic radionuclides at the lower limit of 100 nanocuries per gram. It would be equivalent to a larger mass of low-level waste, since the concentration in such waste (by definition) is less than 100 nanocuries per gram.

limit excludes uranium and radon. The limit of 30 micrograms per liter of uranium is set on the basis of heavy metal toxicity. However, this amount of uranium causes some amount of harm as a result of its radioactivity. Recent science indicates that the harm from the heavy metal aspects of uranium may be reinforced by its radioactivity. (See *Section VI. Other risks and radionuclides*, below). Hence, reconsideration of a variety of issues is warranted. In such reconsideration, it would be practical and less costly to separate out alpha-emitting, long-lived transuranic radionuclides. This is because the vast majority of water systems will not require any testing for alpha-emitting, long-lived transuranic radionuclides since they are not at risk.

IV. Costs

Public water systems are not at present contaminated at or near the requested MCL for alpha-emitting, long-lived transuranic radionuclides. A strengthened alpha-TRU drinking water standard is preventive rather than remedial. Only a small, one-time cost for an initial set of baseline samples is anticipated for those water systems that draw water from sources that include DOE sites with significant plutonium waste or soil contamination in drainage areas. We recommend that this one-time cost be borne by the DOE.

Public water systems are not at present contaminated at or near the requested MCL for alpha-emitting, long-lived transuranic radionuclides.

Since no known contamination of public water systems above 0.15 picocuries per liter of alpha-emitting, long-lived transuranic radionuclides exists, no further action would be required of public water systems and no further costs would be incurred provided there is sufficiently thorough monitoring by the DOE, coupled with remediation programs that are suited to free release of the sites in the long term. This will be sufficient to protect downstream surface waters and underground water systems. The DOE is supposed to carry out such monitoring in any case and therefore no additional, ongoing monitoring costs are anticipated.

The Department of Energy, which is responsible for management of almost all the wastes and materials that pose risks of water contamination with alpha-emitting, long-lived transuranic radionuclides, is supposed to take adequate remedial action at sites like the Idaho National Laboratory, Hanford, the Savannah River Site, and Los Alamos National Laboratory. If it does so, no remediation costs for public water systems would be required under our recommended changes to the National Primary Drinking Water Regulations.

The costs of not tightening the standards would be to signal that remediation of nuclear weapons sites with large inventories of plutonium in the waste could proceed without adequate attention to safe drinking water health protection goals. DOE could then remediate these sites and declare them cleaned up without reference to a science-based drinking water standard that corresponds to current understanding of plutonium movement and irradiation of the human body. Finally, some remediation actions could, in the long run, pollute the water above drinking water standards, and worse, be irremediable. No known technology could remediate vast bodies of water such as the Savannah

River or the Snake River Plan Aquifer if, once polluted, the aim is to reduce pollution from a few picocuries per liter to sub-picocurie per liter levels.

V. Estimating the impact of residual radioactivity

Vast areas of land and huge amounts of water remain contaminated with dangerous long-lived radionuclides from operations of nuclear weapons facilities.[34] The DOE has been given the task to clean up these sites. It is therefore of great importance that the levels of residual radioactivity meet strict standards that will protect the health of individuals of this and future generations that will be exposed to the residual contamination.

In the early 1990s, the DOE embarked on a cooperative process with the EPA to develop national cleanup standards, but the DOE pulled out of the process abruptly in 1996 without any plans for its resumption.[35] Since then, the DOE has proceeded on a site-by-site basis that has led to a welter of proposals for cleanup using various scenarios.

At the Savannah River Site in South Carolina, the DOE is grouting high-level waste in tanks as if it were low-level waste. This waste contains significant amounts of transuranic radionuclides. For instance, the residual waste in Tank 19, which has been grouted, had a concentration of plutonium 14 times above the EPA 100 nanocurie-per-gram limit for transuranic waste. DOE is grouting large amounts of plutonium in the tanks even though it has not yet obtained convincing evidence of the durability of grout. The tanks are buried underground in the watershed of the Savannah River, one of the most important rivers in the South Carolina-Georgia region. Experimental and field data leave room for considerable skepticism as to its performance. IEER's evaluation of the state of the research on grout indicates that the performance of grout remains highly uncertain. There is at present no sound basis, whether in experiment or in field data, to assume that leaving large amounts of grouted alpha-emitting, long-lived transuranic radionuclides in the tanks would be protective of the Savannah River.[36]

A large part of the urgency that our recommendations be incorporated into EPA's forthcoming review of MCLs for radionuclides in drinking water derives from the fact that, in 2004, Congress passed a law allowing DOE to reclassify residual high-level waste as incidental waste at its South Carolina and Idaho sites. The law did not set any limits as to the residual radioactivity in waste so reclassified.[37] Several long-lived radionuclides, including plutonium isotopes, strontium-90, and cesium-137, may be grouted in the tanks or disposed of in shallow saltstone vaults. A realistic framework to guide DOE's decision-making, so that it does not endanger crucial water resources, is therefore of urgent and immense importance.

The consequences of the DOE cleanup policy on the concentrations of residual transuranic contamination in the soil and their potential effect on the health of individuals are discussed in a study by IEER entitled *Setting Cleanup Standards to Protect Future Generations: The Scientific*

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[34] OTA 1991.
[35] Nichols 1996.
[36] Smith 2004 and Makhijani and Boyd, 2004.
[37] PL 108-375, 2004, Sec. 3116.

Basis of the Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats, December 2001.[38] In this study, IEER showed that the specific assumptions about future use have a major impact on what are considered acceptable residual radioactivity levels. A large part of this result is because different future site use scenarios have different assumptions about the use of water and food from the contaminated area in question. Since some radionuclides, including the alpha-emitting, long-lived transuranic radionuclides discussed in this report, are very long-lived, a basic assumption that there will be loss of institutional control over the long-term is essential to sound planning and cleanup.

However, even the adoption of a subsistence farmer scenario as the basis for cleanup cannot assure that levels for residual radioactivity on contaminated sites will be set in a manner that is protective of health and the environment. This is because the translation of residual levels into radiation dose and risk estimates requires the use of complex models and assumptions about the behavior of radionuclides in the environment. For instance, the amount of rainfall, the mobility of radionuclides in specific soil conditions, the porosity of the soil, the solubility of the radionuclides under various circumstances, and the rate of soil erosion are among the critical parameters that need to be known and characterized.

At present, remediation levels are typically assessed by the use of a model developed by Argonne National Laboratory called RESRAD (for residual radioactivity).[39] This computer code is complex and has, over the years, been developed to consider pathways for movement of radioactivity in a sophisticated way. Yet, it does not contain libraries of dose conversion factors for, and thus does not account for, infants or for young people at sensitive times in their hormonal development or for the fetus at various stages of fetal development. The estimation of doses to various segments of the population at sensitive periods in their lives may also require consideration of how the environmental pathways and the systems in the human body are represented in the model's source code.

The RESRAD source code is closely held by the U.S. government; it is not public. Ostensibly, the official rationale is that since RESRAD is used for regulatory decisions, such as those that are made in the context of cleanup at nuclear weapons sites, it should not be made public. However, we do not accept this rationale. The code can be made public and can be an open source code, available for modification in the same manner as the Linux operating system source code. That has resulted in its improvement and efficiency, without problems actually creeping into mass use of the code as an operating system. The U.S. government can surely retain its version of the code for regulatory purposes while making the source code publicly available for examination and improvement. If at a certain stage, the code is improved in a manner that regulatory bodies such as the EPA consider it useful for regulatory purposes, they will freely be able to adopt the changes but will be under no obligation to so.

[38] Makhijani and Gopal 2001.
[39] RESRAD.

VI. Other risks and radionuclides

New scientific work on radiation protection is currently emerging, for instance in relation to (i) protection of the embryo/fetus and infant, (ii) non-cancer effects of exposure to certain radionuclides, (iii) potential synergistic effects of exposure to certain chemicals, such as hormonally active chemicals, and exposure to radiation, (iv) the need for protection of key non-human species and ecosystems, and (v) the synergisms indicated for certain effects between the heavy metal toxicity component of uranium and its radiotoxicity. However, these are still emerging areas of concern, where the risks are not quantitatively well established. How such risks are to be considered in the context of a review of drinking water MCLs will be considered in a future IEER report.

Recent developments in radiobiology and health effects research have increased understanding of radiation doses during fetal development. They indicate that non-cancer health effects resulting from fetal exposure to radiation could be very important. For instance, ICRP 90 emphasizes that the central nervous system is especially vulnerable during a certain period of fetal development:

> …[B]iological systems with a high fraction of proliferating cells show high radiation responsiveness. High rates of cell proliferation are found throughout prenatal development….Development of the central nervous system starts during the first weeks of embryonic development and continues through the early postnatal period. Thus development of the central nervous system occurs over a very long period, during which it is especially vulnerable. It has been found that the development of this system is very frequently disturbed by ionising radiation, so special emphasis has to be given to these biological processes.[40]

A variety of end points (disease outcomes) are at issue, from central nervous system development to cancer to birth defects to increased risk of miscarriages. Further, these end points raise the issue of the combined effects of other pollutants with radiation more insistently that ever before. For instance, one might ask about the potential for non-linear effects caused by exposure to both lead and radiation or mercury and radiation. One might also ask about the combined effects of exposure to endocrine disrupting chemicals and radiation in relation to a number of end points. These are areas still in a relatively early stage in the science compared to the understanding of radiogenic cancer induction. For these areas, which concern non-cancer end points as a result of fetal exposure, for instance, the conversion of the scientific data in publications such as ICRP 88 and ICRP 90 into regulations for health and environmental protection will take considerable time.[41] The EPA has not even published the necessary guidance documents as yet.

Recent research, much of it done at the Armed Forces Radiobiology Research Institute, pursuant to concerns about the health effects of depleted uranium, points to a surprising variety of harmful health effects of uranium. A recent literature survey by IEER summarized the situation as follows:

> The understanding of the risks of cancer due to radiation exposure from depleted uranium and kidney damage due to its heavy metal properties has expanded greatly in recent years. In addition, evidence is amassing that raises serious concerns regarding the impact of

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[40] ICRP-90, 2003, page 9.
[41] ICRP-88, 2002; ICRP-90, 2003.

> chronic exposure to DU in relation to a number of other health issues. Studies in humans and animals have shown that uranium can concentrate in the skeleton, liver, kidneys, testes, and brain. In addition, rats implanted with DU pellets have also shown uranium concentrating in the heart, lung tissue, ovaries, and lymph nodes among other tissues. Research, primarily but not exclusively conducted since the 1991 Gulf War, indicates that exposure to uranium may be
>
> Mutagenic
> Cytotoxic
> Tumorigenic
> Teratogenic
> and Neurotoxic, including in a manner analogous to exposure to lead.
>
> Additionally…some research has also provided indications that there may be a synergistic effect between the heavy metal aspect of exposure to uranium and its radioactive effects….Current research conducted at the Armed Forces Radiobiology Research Institute (AFRRI) indicates that "[i]n the case of DU, cells not traversed by an alpha particle may be vulnerable to radiation-induced effects as well as chemically-induced effects." Additional work at the AFRRI has also shown that depleted uranium can cause oxidative DNA damage and thus provides the first indication that uranium's radiological and chemical affects might potentially play both a tumor initiating and a tumor promoting role. [42]

In other words, uranium may be a kind of radioactive lead, with serious health effects arising both from its heavy metal toxicity and its radioactivity. Should these risks be proven to be substantial, there may be a need to include new limits in the National Primary Drinking Water Regulations relating to the combined radioactive and heavy metal toxic effects of uranium.

There are also a variety of other issues associated with the potential interaction of hormonally active chemicals with radiation, and particular certain radionuclides, like iodine-129, which concentrates in the thyroid and crosses the placenta. The development of certain cancers, like breast cancer, is linked to hormonal systems, possibly to hormonally active chemical pollutants, and to radiation. Hence the issues associated with health protection in regard to certain cancers are likely to be much more complex.

Finally, there are issues that were once recognized but that appear to have been forgotten or ignored in the context of protection of public health from radiation. Consider the following passage from ICRP 2 that occurs in the context of a discussion of bone doses and the calculations that are the subject of this report:

> Certainly, if a major portion of the hematopoietic system were irradiated, e.g., concurrently from the spleen-seeking Po^{210} and from the bone-seeking Ra^{226}, the biological damage would be greater than if only a part of it were irradiated. *It has been shown that in some cases a synergistic effect results when several organs of the body are irradiated simultaneously*.[43]

Some of these synergistic effects are already implicit in the estimates of risk made from Hiroshima/Nagasaki survivors (since they received whole body radiation – i.e., all organs were

[42] Makhijani and Smith 2005, pages 9-10. Typos corrected.
[43] ICRP-2, 1959, page 14, emphasis added.

irradiated). However, others involving internal deposition and that selectively target certain organs may have more complex effects. This indicates that it is important to maintain regulations in the form of dose limits to maximally exposed organs in regulations relating to protection of public health, such as the National Primary Drinking Water Regulations (40 CFR 141), *Environmental Radiation Protection Standards for Nuclear Power Operations* (40 CFR 190), and *Environmental Radiation Protection Standards For Management And Disposal Of Spent Nuclear Fuel, High-Level And Transuranic Radioactive Wastes* (40 CFR 191). At the present time, there is still a significant amount of scientific work that remains to be done in a variety of areas before this framework can be changed into a better one from the point of view of health, environment, future generations, and the economy.

Consideration of changes in radiation protection in the medium- and long-term, that would take into account emerging scientific and risk issues such as those discussed in this section, is needed for a variety of reasons, some of which are mentioned above. However, this will be a complex and difficult task which must be done with due deliberation. It will also likely go far beyond safe drinking water standards. At the present time, the safety and protection of water resources from irreversible contamination with alpha-emitting, long-lived transuranic radionuclides as a result of ongoing activities by the Department of Energy cannot be allowed to be deferred to the longer, more comprehensive social, economic, and health discussion related to the protection of health from radioactive and toxic pollution. It must be considered as part of the EPA's 2006 review of standards for radionuclides in drinking water. A maximum contaminant level for plutonium that is 100 times too lax based on the intent and letter of the Safe Drinking Water Act must not be allowed to persist.

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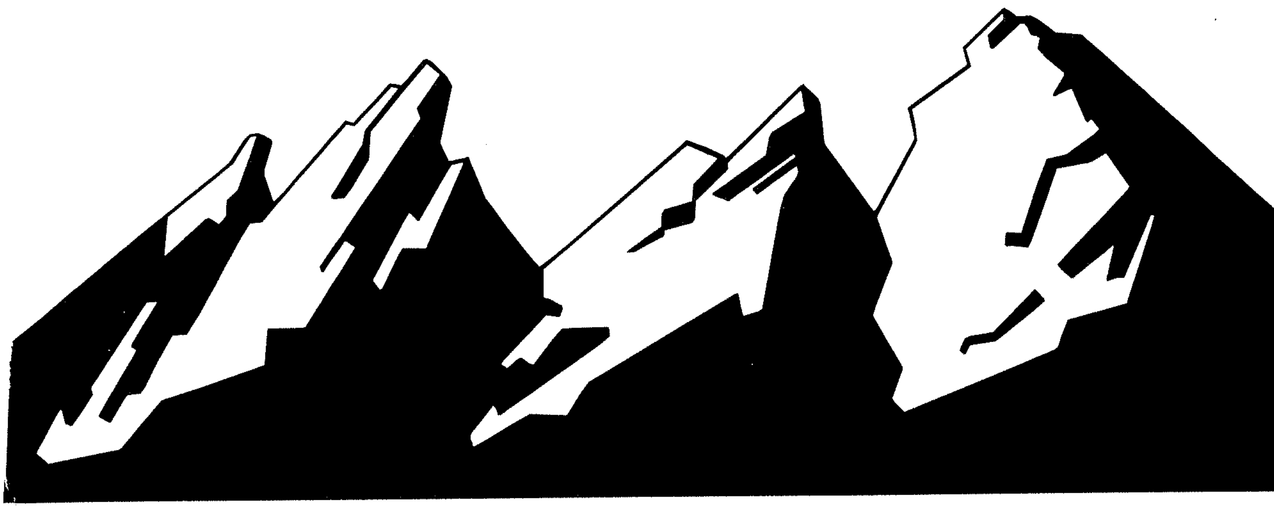
Appendix G



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Dumping on Federalism

Robert J. Cynkar

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DUMPING ON FEDERALISM

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INTRODUCTION

One piece of news clearly has not been well-reported, at least west of the Mississippi. It appears that the demand for troops in Iraq and elsewhere is just too great. Congress has found it necessary to reinstitute the draft. Interestingly, the only people to be drafted are young men and women from Colorado. One legislator was quoted as saying: "Those people out there are just having too much fun, particularly at the university in Boulder. Serving their country will be good for them."

Of course, informed Coloradoans were outraged, wondering if their representatives were asleep at the switch. In fact, they were just out voted. The members of Congress from the other forty-nine states had simply gotten together and agreed that it was better for the members from one state, rather than from every state, to take the inevitable political heat for this move. Conveniently, Colorado seemed to have just the right population of draft-age men and women, and so ganging up on Colorado was, well, in the national interest. Someone had to go, after all.

This story about the draft is as outrageous as it is fanciful. Ganging up like that on one state for no good reason strikes any fair (and modestly informed) observer as fundamentally at war with the premises of our federal system. Yet, it is said that truth is sometimes stranger than fiction, and that is certainly true of the process that led to siting the nation's first high-level nuclear waste repository in Yucca Mountain, Nevada. This is the tale of forty-nine of Nevada's sister states ganging up to make Nevada bear a national burden for no good reason, except that they had the votes.

There are two strands of this tale. The first is the story of the nation coming to grips with the problem of the permanent, safe disposal of high-level nuclear waste. In most respects, this is the saga of the enact-

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ment of the Nuclear Waste Policy Act of 1982 ("NWPA"),[1] and the related evolution of the regulations promulgated by three different agencies. That evolution, and the selection of Yucca Mountain as the site for this repository, generated litigation in the United States Court of Appeals for the District of Columbia Circuit challenging the selection of Yucca Mountain on a variety of grounds, including the constitutional issue we will consider here.

The second strand, by contrast, is as old as the Republic and our federal structure, arising from what the Framers of the Constitution saw as the conundrum of *imperium in imperio*—sovereign power within sovereign power.[2] What the Framers did not lose sight of is the fact that we do not have a unified national government. Our country is a federation of sovereign states whose existence preceded the Union. The existence of these sovereign states is inherent in the Union's structure, and so there is very little direct discussion of state sovereignty in the Constitution. As one of the legal team members representing Nevada, Brian Koukoutchos, aptly put it, "Just as islands need not advertise that they are surrounded by water, because that fact inheres in the very definition of island, so the Constitution should not be expected to dwell on state sovereignty for the simple reason that state sovereignty just is."

At the outset of the NWPA process, neutral criteria were used to determine which state was to be burdened with this waste dump. Logically, those criteria centered on the physical attributes of potential sites, such as geology and hydrology, that determine the ability of any site to isolate highly radioactive waste for generations. But once it was discovered that Yucca Mountain's geologic profile was unsuitable for this purpose, the involved federal agencies rewrote the governing rules to create a new standard that only applies to Yucca Mountain and largely relies on man-made containers to isolate this extraordinarily toxic material. Under such a disposal regime, nothing distinguishes Yucca Mountain, and many sites across the country could serve as home to the nation's nuclear waste dump.

Nevada contends that siting the nation's nuclear waste repository at Yucca Mountain is unconstitutional because it has become a naked act of arbitrary political will that singles out Nevada and invades its sovereignty. The constitutional argument mounted on behalf of Nevada, and offered here, is undeniably novel—there is no existing authority precisely on point. But the argument is also ancient, arising from principles at the root of much of our constitutional jurisprudence.

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1. 42 U.S.C. §§ 10101-10270 (2000).
2. *See* FORREST MCDONALD, STATES' RIGHTS AND THE UNION: *Imperium in Imperio,* 1776-1876, at 1-5 (2000).

The first section of this article will review the nature of the nuclear waste problem and Congress's efforts to establish the first national high-level radioactive waste disposal facility. That section will examine the actions of the Executive Branch departments and agencies to implement Congress's disposal scheme, including the dramatic shift in regulatory standards to ensure that Yucca Mountain would be approved as the repository site.

The second section of the article will identify the principles of federalism that animate the Constitution by examining various precedents in which those principles are manifested. The third section of the article will describe the constitutional argument Nevada mounted against the siting of the nation's nuclear waste dump at Yucca Mountain based on these principles of federalism. The article concludes with a discussion of the D.C. Circuit's adjudication of that argument (among other arguments raised by Nevada) in the series of cases consolidated as *Nuclear Energy Institute, Inc. v. Environmental Protection Agency ("NEI")*.[3]

I. THE NUCLEAR WASTE PROBLEM

The operation of nuclear power plants, research reactors, and military reactors all produce spent fuel. Spent fuel is lethally radioactive; indeed spent fuel is comprised of the most dangerous substances known. For example, if plutonium is ingested through drinking water, it "stays in the body for decades, exposing organs and tissues to radiation, and increasing the risk of cancer."[4] Compounding the danger, spent fuel is an extraordinary hazard not only to those exposed to it, but also, because these materials are "mutagenic," they can pass on biological damage to future generations.[5] The danger posed by these wastes lasts for millennia.[6] The radioactive elements in these wastes have "half-lives" of millions of years.[7] Making the situation even worse, some of these isotopes decay into even more dangerous substances. For example, americium-243 decays, over twenty-thousand years, into the much more dangerous and toxic plutonium-239. "Thus, the toxicity of americium-243 de-

3. 373 F.3d 1251 (D.C. Cir. 2004).

4. U.S. Environmental Protection Agency, *Radiation Information: Plutonium* (2004), *available at* http://www.epa.gov/radiation/radionuclides/plutonium.htm.

5. H.R. Rep. No. 97-785, Pt. 1, at 46 (1982).

6. OFFICE OF CIVILIAN RADIOACTIVE WASTE MGMT., DEP'T OF ENERGY, FINAL ENVIRONMENTAL IMPACT STATEMENT FOR A GEOLOGIC REPOSITORY FOR THE DISPOSAL OF SPENT NUCLEAR FUEL AND HIGH-LEVEL RADIOACTIVE WASTE AT YUCCA MOUNTAIN, NYE COUNTY, NEVADA, 1-13 (2002) [hereinafter 2002 Final EIS].

7. *See NEI*, 373 F.3d at 1258. A half-life is the time it takes a substance to decay to half of its initial radioactivity level. H.R. Rep. No. 97-785, Pt. 1, at 46.

creases for about 20,000 years, after which it becomes more toxic than it was originally."[8]

This spent fuel and radioactive waste has been produced at 131 sites in thirty-nines States (not including Nevada) at a rate of about 2,000 metric tons per year.[9] Storage of such highly toxic material obviously poses a unique challenge. The logistics of storage are complicated by the fact that, in the process of decay, the wastes produce heat so intense it can boil water out of desert rocks.[10] As a result, spent fuel must be cooled for three to five years in pools at reactor sites before it can even be handled or transported.[11] Initially, it was these pools that served as storage for spent fuel. As they became filled to capacity, however, utilities had to turn to above-ground storage facilities, storing fuel in casks that are continuously monitored and secured by armed guards. The Nuclear Regulatory Commission ("NRC"), which licenses such "dry storage" facilities, has determined they can remain safe for at least 100 years,[12] though the industry has testified that spent fuel "can be stored for centuries safely" at such facilities.[13] Twenty-four dry storage facilities are in operation, with the construction of twenty-one more in the planning stage.[14] Also, under development by utilities is a dry storage facility in Utah that will hold nearly 87 percent of the industry's existing spent fuel.[15]

Another, comparatively short-lived, approach was the notion that spent fuel should be "reprocessed" to extract the reusable uranium and plutonium from it. Reprocessing is important in the history of public efforts to address the disposal of high-level nuclear waste because for years a solution to the problem was postponed because it was assumed spent

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8. H.R. Rep. No. 97-785, Pt. 1, at 46.

9. *See* U.S. NUCLEAR REGULATORY COMMISSION, INFORMATION DIGEST, NUREG 1350 (2003), *available at* http://www.nrc.gov/readingrm/doccollections/nuregs/staff/sr1350/#high_level; Nuclear Energy Institute, *High-Level "Nuclear Waste" Is Really Used Nuclear Fuel* (2004), *available at* http://www.nei.org/doc.aspcatnum=2&catid=62&docid=&format=print.

10. *See* 2002 Final EIS, *supra* note 6, at 2-9 to 2-11.

11. H.R. Rep. No. 97-785, Pt. 1, at 40.

12. Ivan Selin, Chairman, U.S. Nuclear Regulatory Comm'n, Remarks Before the International High-Level Waste Management Conference, at 3 (May 1, 1995) (transcript on file with author).

13. Nuclear Waste Disposal Joint Hearings on S. 637 and S. 1662 Before the S. Comm. on Energy and Natural Res. and the Subcomm. on Nuclear Regulation of the S. Comm. on Env't and Pub. Works, 97th Cong. 358 (1981) (statement of Sherwood Smith, Chairman & CEO, Carolina Power & Light Co., on behalf of the American Nuclear Energy Council, the Edison Electric Institute, and the Utility Nuclear Waste Management Group).

14. Kimberly A. Gruss, Senior Materials Engineer, National Resource Council, U.S. Experience With Dry Cask Storage, A Regulator's Perspective, Presentation at the Dry Spent Fuel Technology Technical Meeting, at 23-24 (June 10-14, 2002) (transcript on file with author).

15. 2002 Final EIS, *supra* note 6 at 1-22.

fuel would be reprocessed. This reprocessing would leave liquid radioactive wastes which would then be "vitrified," or immobilized, into solid glass logs that can be stored safely indefinitely.[16] However, in 1976, the government, for a combination of non-proliferation and economic reasons, ended reprocessing in the United States.[17]

A. *The Solution: Geologic Disposal*

In 1957, the National Academy of Sciences ("NAS") completed the nation's first comprehensive study of the management and disposal of nuclear waste.[18] "Unlike the disposal of any other type of waste," NAS said, "the hazard related to radioactive waste is so great that no element of doubt should be allowed to exist regarding safety."[19] The best option to meet that standard of certainty, according to NAS, was to bury this waste deep underground in a stable geologic setting that would permanently isolate it from human beings and the rest of the environment. Particularly promising for this task are salt deposits, because "no water can pass through salt" and its "[f]ractures are self-sealing."[20] The bottom line, for NAS, was that we should "return[ ] those wastes to nature in some place where they can be held for very, very long periods of time without jeopardy to our environment or property."[21]

With the endorsement of NAS, "deep geologic isolation" became the cornerstone of every repository program in the world, including what became the U.S. repository program. In 1980, President Jimmy Carter ordered the Department of Energy ("DOE") to prepare a full Environmental Impact Statement ("EIS") recommending an alternative to permanently dispose of high-level nuclear waste.[22] Although DOE's analysis was informed by NAS's endorsement of geologic disposal, DOE evaluated every conceivable method of disposal, including subseabed and ice-sheet disposal, deep-well injection, transmutation, and even disposal in outer space.[23] In the end, the solution proposed by DOE was to dispose of spent fuel in "mined repositories deep within the geologic

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16. *See id.* at 1-7.
17. H.R. Rep. No. 97-491, Pt. 1, at 27 (1982).
18. COMM. ON WASTE DISPOSAL, NATIONAL RESEARCH COUNCIL, THE DISPOSAL OF RADIOACTIVE WASTE ON LAND (1957).
19. *Id.* at 3.
20. *Id.* at 4.
21. *Id.* at 18.
22. 2002 Final EIS, *supra* note 6 at 1-9.
23. 1 ASSISTANT SEC'Y FOR NUCLEAR ENERGY, DEP'T OF ENERGY, FINAL ENVIRONMENTAL IMPACT STATEMENT: MANAGEMENT OF COMMERCIALLY GENERATED RADIOACTIVE WASTE § 1.4 (1980).

formations of the earth,"[24] which would be so effective that "it is extremely improbable that wastes in biologically important concentrations would ever reach the human environment."[25]

The effectiveness of geologic isolation did not mean that man-made, "engineered barriers" were to play no role. DOE explained:

> The multiple barriers that could contain nuclear waste in deep mined repositories fall into two categories (1) geologic or natural barriers and (2) engineered barriers. Geologic barriers are expected to provide isolation of the waste for at least 10,000 years after the waste is emplaced in a repository and probably will provide isolation for millennia thereafter. Engineered barriers are those designed to assure total containment of the waste within the disposal package during an initial period during which most of the intermediate-lived fission products decay. This time period might be as long as 1000 years. . . .[26]

DOE emphasized that "[m]ultiple barriers are intended to act independently to prevent waste migration and enhance isolation."[27] "[T]he engineered components of the multibarrier system would be of greatest importance in the short term and the repository medium and the surrounding geology would be the critical elements over long periods of time."[28] Echoing NAS, DOE concluded, "[t]he host rock with its properties provides the justification for geologic disposal and is the main element in containing the waste within the repository and in isolating the waste from man's environment over the long term."[29] The bottom line for DOE at this time was clear: the geologic setting should be capable of containing wastes to ensure *long-term* safety. That meant isolating this waste for *250,000 to 500,000 years*.[30]

Together, the NAS study and the EIS established the scientific framework for evaluating the suitability of a mined geologic repository. It was this scientific foundation that informed Congress as it considered nuclear waste legislation beginning in 1980, culminating with in enactment of the Nuclear Waste Policy Act ("NWPA") two years later.

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24. *Id.* at § 5.1.
25. *Id.* at § 1.3.4.
26. *Id.* at § 5.1.
27. 3 ASSISTANT SEC'Y FOR NUCLEAR ENERGY, DEP'T OF ENERGY, FINAL ENVIRONMENTAL IMPACT STATEMENT: MANAGEMENT OF COMMERCIALLY GENERATED RADIOACTIVE WASTE 272 (Oct. 1980) [hereinafter 1980 Final EIS (vol.3)].
28. *Id.* at 281.
29. 2 ASSISTANT SEC'Y FOR NUCLEAR ENERGY, DEP'T OF ENERGY, FINAL ENVIRONMENTAL IMPACT STATEMENT: MANAGEMENT OF COMMERCIALLY GENERATED RADIOACTIVE WASTE at B.15 (1980).
30. 1980 Final EIS (vol.3), *supra* note 27 at 360-61.

B. Congress Acts: The Nuclear Waste Policy Act

At the outset, Congress considered approaches to nuclear waste disposal that would dispose of *reprocessed* wastes from spent fuel, not the spent fuel itself.[31] The initial proposal relied primarily on engineered barriers to dispose of vitrified reprocessed wastes.[32] Importantly, DOE opposed the bill on grounds that it was inappropriate to rely primarily on engineered barriers *even for repositories without spent fuel.* In DOE's words,

> Engineered barriers are an essential ingredient in a technically conservative approach to an actual repository, but we do not feel that the existence of such barriers should be used as a basis for a less careful selection of an acceptable geologic media.[33]

As work continued on the Hill, the key committees began to recognize that, given the policy shift away from reprocessing, it was much more likely that the waste to be disposed of was going to be the far more radioactive and dangerous spent fuel itself.[34] The far more dangerous and longer-term risks posed by the disposal of unreprocessed spent fuel meant that some elements of this waste would need "to be isolated for at least 245,000 years."[35] Secure storage for such a phenomenal length of time led away from reliance on any engineered barrier back to the only material that has been around for that long—rock. As the House Commerce Committee put it:

> [T]he ability of any man-made containers to endure for a quarter of a million years is obviated by the fact that the ultimate barrier which prohibits the release of any radioactivity into the biosphere is the geologic media itself. The effectiveness of this method is dependent upon finding a geologic media whose integrity is intact, meaning that it does not have openings which would allow radioactivity to escape into the atmosphere or into the ground water.[36]

The logic governing the choice of a site for a repository was then

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31. *See* H.R. Rep. No. 96-1156, Pt. 1, at 25 (1980).

32. *Id.* at 17-18.

33. *Id.* at 37.

34. *See, e.g.*, S. Rep. No. 96-548, at 11 (1980) (noting the deferral of "commercial reprocessing of spent nuclear fuel for the indefinite future"); H.R. Rep. No. 96-1156, Pt. 2, at 2 (1980) (recognizing that "the option to reprocess spent nuclear fuel is presently foreclosed to the nuclear industry," making it "necessary at this time to do preliminary planning on the basis of geologic disposal of spent fuel").

35. H.R. Rep. No. 96-1156, pt. 3, at 13 (1980).

36. *Id.* at 14.

quite clear. A repository could not just be put anywhere; the site must meet specific requirements. As the House Committee cautioned at the time, "[w]hile it is believed that there are locations within the United States which meet these requirements, it is further believed that the number of such locations is limited."[37]

In this way, reliance on the geology of a repository's site became an essential element of the nation's nuclear waste disposal effort. Finally, in 1982, in the NWPA, the repository program Congress fashioned embodied a

> [c]ommitment to a waste disposal technology relying on primary geologic containment provided by a solid rock formation located deep underground, together with containment by engineered barriers including the form and packaging of the nuclear waste, which will provide safe containment of the waste without reliance on human monitoring and maintenance after an initial period of testing and subsequent closure of the repository.[38]

Selecting a repository site, then, means

> finding a geologic medium whose integrity is intact, meaning that it does not have openings which would allow radioactivity to escape into the atmosphere or into the ground water. The structural integrity of the geologic medium would also have to be stable enough to maintain its integrity during the period of time in which these materials remain radioactive.[39]

The focus on the geology into which a nuclear waste repository will be inserted is evident from the threshold of the NWPA's definitions through the complex process of site selection and repository development established by the statute. Thus, the NWPA defines "repository" as a system to be used for "permanent deep geologic disposal."[40] "Candidate sites" are defined as areas "within a geologic and hydrologic system" that undergo DOE site characterization,[41] which, in turn, means DOE activities "undertaken to establish the geologic condition" of a candidate site.[42] The statute goes on to require DOE to establish guidelines for the selection and recommendation of sites, which "shall specify de-

37. *Id.*

38. H.R. Rep. No. 97-491, Pt. 1, at 30 (1982). *See also* H.R. Rep. No. 97-785, Pt. 1, at 48 (1982).

39. H.R. Rep. No. 97-785, Pt. 1, at 48.

40. 42 U.S.C. § 10101(18) (2000).

41. § 10101(4).

42. § 10101(21).

tailed geologic considerations that shall be primary criteria" for site selection.[43] Moreover, "[s]uch guidelines shall specify factors that qualify or disqualify any site from development as a repository, including factors pertaining to . . . hydrology, geophysics [and] seismic activity. . . ."[44]

A central purpose of the NWPA was to "define the relationship between the Federal Government and the State governments with respect to the disposal of such waste and spent fuel."[45] Three federal agencies were assigned responsibility for the assessment and potential development of proposed repositories. DOE was to evaluate and recommend potential repository sites, and then build and operate the repositories.[46] The NRC was to determine whether to license the repositories in accordance with statutory and regulatory standards.[47] The Environmental Protection Agency ("EPA") was to set the radiological release standards applicable to repositories.[48]

As originally enacted, the NWPA process for the development of a repository was clearly designed to find a site that met the critical geologic attributes essential to the safe, secure, and long—term disposal of nuclear waste. The Secretary of Energy was assigned the task of evaluating potential candidate sites in accordance with the standards established by the statute, and then nominating to the President at least five sites to be subjected to further research as possible candidates to become the first repository.[49] The Secretary was then to narrow this list and recommend three sites to the President by January 1, 1985, which would then proceed to the detailed site characterization stage.[50] The President, in turn, was to decide whether each recommended site should proceed to site characterization.[51]

Once the sites were fully characterized, the Secretary was to recommend to the President a single site to be developed as a repository.[52] Upon such a recommendation, the President was authorized to designate the site to Congress. The President's site designation was automatically to "take effect" after sixty days unless the state in which the site was lo-

43. § 10132(a).
44. *Id.*
45. § 10131(b)(3).
46. § 10134.
47. §§ 10134(d), 10141(b).
48. § 10141(a).
49. § 10132(b)(1)(A).
50. §§ 10132(b)(1)(B), 10101(21).
51. § 10132(c). The National Waste Policy Act established a similar process (with different timetables) for the characterization of sites for possible selection as a second repository. 42 U.S.C. § 10132(b)(1)(c) (2000).
52. § 10134(a).

cated submitted to Congress a "notice of disapproval."[53] If the state did disapprove, the selection of the site could not become effective unless, during the first ninety days after receipt of the notice, Congress passed a "resolution of repository siting approval" overriding the notice of disapproval, and such resolution became law.[54] The precise text of the resolution was dictated by the NWPA, was not amendable, and was considered by the House and the Senate under severely expedited and abbreviated procedures that limited debate, truncated opportunities for normal legislative deliberation, and omitted many of the usual procedural protections for minority interests.[55]

It is important to underscore the fact that Congress did not assume that the site characterization process would automatically lead to the selection of that site for the repository. Quite the contrary, Congress fully appreciated that the federal government could spend considerable time and resources investigating a particular site, only to conclude that the site was unsuitable. As one House Committee noted:

> The risk that a site which had been considered probably adequate for development could be abandoned after significant commitment had been made to the site is a technically unavoidable aspect of repository development. It is a result of the limit of our ability to know with certainty all the characteristics of a rock formation deep underground until the rock site has actually been excavated and surveyed from the "horizon" or level of the repository.[56]

The DOE, NRC, and EPA published rules intended to discharge their obligations under the NWPA.[57] In its first set of site suitability rules in 1984, DOE paid careful attention to the geologic requirements and the physical qualifying and disqualifying conditions recommended by NAS and the 1980 EIS, and required by the NWPA.[58] The NRC concurred in the draft regulations, but only upon DOE's promise to specify "that engineered barriers cannot constitute a compensating measure for deficiencies" in physical attributes of the site.[59] The EPA also warned DOE not to over-rely on engineered barriers.[60]

DOE's final rules accordingly provided that "engineered barriers shall not be used to compensate for an inadequate site; mask the innate

53. § 10135(b).
54. § 10135(c).
55. § 10135(a), (d), (e).
56. H.R. REP. NO. 97-491, Pt. 1, at 32 (1982).
57. 10 C.F.R. Pt. 960 and 60 (2004), 40 C.F.R. Pt. 191 (2003), respectively.
58. *See* 49 Fed. Reg. 47,714 & 47,718 (Dec. 6, 1984).
59. 49 Fed. Reg. at 47,727.
60. 49 Fed. Reg. at 47,727.

deficiencies of a site; disguise the strengths and weaknesses of a site and the overall system; and mask differences between sites when they are compared."[61] As the NWPA requires, DOE also specified both qualifying and disqualifying conditions for a site. A key disqualifying condition was that of groundwater travel time, since "[t]he most likely mechanism for the release of radionuclides from a repository to the accessible environment is transport by ground water."[62] Accordingly, DOE specified that surface rainwater trickling through the repository site must take no less than 1,000 years to descend from the repository into the water table and the accessible environment.[63]

C. *The Focus on Yucca Mountain*

In 1986, complying with the NWPA timeline, the Secretary of Energy recommended and the President approved three sites for detailed site characterization: Yucca Mountain, Nevada; Deaf Smith County, Texas; and Hanford, Washington.[64] However, in 1987, due to rising cost estimates for site characterization at the three sites chosen by DOE, Congress amended the NWPA to provide that Yucca Mountain would be the only site characterized.[65] Significantly, however, in narrowing site characterization to Yucca Mountain, Congress did *not* prejudge the Yucca site's suitability, but instead made clear that "[i]f the Secretary at any time determines the [Yucca Mountain] site to be unsuitable for development as a repository," he was to terminate all activities and notify Congress.[66] Moreover, Congress did nothing to change the physical siting requirements it had enacted in the original NWPA. Although the focus for site characterization was now solely on Yucca Mountain, the statute continued to mandate that the original criteria for evaluating the suitability of a site still governed that process.[67]

As commanded by the 1987 amendments of the NWPA, DOE released a "Site Characterization Plan" that underscored that the 1987 changes did nothing to disturb the standards for evaluating a repository site.[68] Indeed, DOE stressed that repository safety was inextricably

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61. 10 C.F.R. § 960.3-1-5(e) (2004).
62. 49 Fed. Reg. at 47,732.
63. 10 C.F.R. § 960.4-2-1(d) (2004).
64. *See* Nevada v. Watkins, 939 F.2d 710, 713 (9th Cir. 1991).
65. *See generally*, Nuclear Waste Policy Amendments Act of 1987, Pub. L. No. 100-203, tit. V, subtit. A.
66. 42 U.S.C. § 10133(c)(3) (2000).
67. § 10133 (b)(1)(A)(iv).
68. *See* U.S. Dept. of Energy Office of Civilian Radioactive Waste Management, Site Characterization Plan: Yucca Mountain Site, Nevada Research and Development Area, Nevada, Vol. I, Pt. A, at I-8-9 (Dec. 1988).

linked to the physical setting, stating that "[g]eologic conditions are intrinsic to the performance of a repository. . . ."[69]

Congress again tinkered with the NWPA in the Energy Policy Act of 1992 ("EnPA") to resolve a long-standing tug-of-war between the NRC and EPA by giving the EPA responsibility to set the primary radiological standards for waste emissions at Yucca Mountain.[70] Again, Congress did nothing in EnPA to alter the NWPA's standards governing the site suitability analysis and the geologic isolation of waste, as DOE subsequently confirmed both in 1994[71] and in 1995.[72]

D. 1996 and Beyond: The Perfect Storm Hits DOE

For more than a decade after enactment of the NWPA, DOE consistently viewed "geologic" isolation as statutorily required and scientifically necessary for the safe, permanent disposal of nuclear waste. It also understood, logically, that the choice of a repository site was a function of its geologic attributes. Then, in 1996, a confluence of events created what was for DOE's bureaucracy, the perfect storm. First, Congress slashed the Yucca Mountain budget for fiscal year 1996 by forty percent,[73] which is by any measure "draconian budget cuts."[74] Second, in *Indiana-Michigan Power Co. v. U.S. Dept. of Energy*,[75] the D.C. Circuit ruled that DOE had an "unconditional obligation" to dispose of utilities' spent fuel by the NWPA's 1998 statutory deadline. In view of DOE's impending breach, the decision presented DOE with potentially crushing financial liability, perhaps up to $56 billion.[76]

Third, and worst of all, ominous results were pouring in from stud-

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69. U.S. Dept. of Energy Office of Civilian Radioactive Waste Management, Site Characterization Plan Overview: Yucca Mountain Site, Nevada Research and Development Area, Nevada, at 16 (Dec. 1988).

70. Energy Policy Act of 1992 § 801(a)(1), note to 42 U.S.C. § 10141 (2000).

71. *See* 59 Fed. Reg. 39,766 (Aug. 4, 1994).

72. *See* 60 Fed. Reg. 47,737-39 (Sept. 14, 1995).

73. U.S. Dept. of Energy, Draft Civilian Radioactive Waste Management Program Plan, DOE/RW-0458 Revision 1, at vi (May 1996).

74. Daniel A. Dreyfus, Director, U.S. Dept. of Energy Office of Civilian Radioactive Waste Management, Program Status and Outlook, Presentation Before the Nuclear Waste Technical Review Board 1996 Winter Meeting, at 1 (Jan. 10, 1996).

75. 88 F.3d 1272, 1275 (D.C. Cir. 1996).

76. Nuclear Energy Inst., DOE To Breach 16-Year Legal Obligation To Manage Used Nuclear Fuel; U.S. Taxpayers Face $56 Billion in Liabilities, at 2 (Jan. 30,1998), *available at* http://www.nei.org/doc.asp?Print=true&DocID=&CatNum=4&CatID=11. *See also* Northern States Power Co. v. U.S. Dept. of Energy, 128 F.3d 754, 759 (D.C. Cir. 1997) (referring to "billions" of dollars of delay-related costs); Alabama Power Co. v. U.S. Dept. of Energy, 307 F.3d 1300, 1302 (11th Cir. 2002) (referring to "tide of litigation arising out of this massive breach").

ies in a five-mile tunnel DOE had bored deep into the Yucca Mountain "unsaturated" zone. It had become apparent that Yucca's geology was incapable of serving as the primary isolation barrier because groundwater flow through the site was far faster than expected. Absent near-perfect performance by man-made barriers, the fast flowing groundwater was likely to carry radioactive particles so quickly that radiological emission standards could never be met. Geologists, for example, discovered chlorine-36 in fractures in the area where the repository was to be constructed.[77] The abundance of this rare isotope meant it had originated from fallout during atmospheric nuclear testing in the 1950s, and suggested that it had migrated from surface rainwater through hundreds of feet of rock in previously unsuspected "fast flow paths."[78] Geologists found pockets of trapped water in what was thought to be the dry, "unsaturated" zone. In some areas, nearly *a million cubic meters* of water were discovered.[79] After further studies, DOE's geologists confirmed that "flow along fast preferential pathways through fractures is a significant and perhaps the dominant flow regime in the unsaturated zone," leading to "travel times of less than 50 years from the land surface to the saturated zone."[80] Far from permanently isolating waste, Yucca Mountain's geology would allow groundwater to carrying radionuclides into the water table far sooner than required to prevent contamination of the human environment.[81]

In 1998, after reviewing DOE's reports to the Nuclear Waste Technical Review Board ("TRB"), which is a board of scientists established by Congress that serves as a technical auditor of DOE's work, Nevada's governor urged DOE to disqualify the Yucca Mountain site.[82] The Secretary's response conceded that DOE's analyses showed that up to 20

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77. D.L.Barr, *et al.*, Bureau of Reclamation and U.S. Geological Survey, Geology of the North Ramp: Stations 4+00 to 28+00, Exploratory Studies Facility, Yucca Mountain Project, Yucca Mountain, Nevada, at 125 (1996).

78. *See* J.T. Fabryka-Martin, *et al.*, Summary Report of Chlorine-36 Studies: Systematic Sampling for Chlorine-36 in the Exploratory Studies Facility, Abstract, at i (March 29, 1996).

79. G.S. BODVARSSON & T.M. BANDURRAGA, DEVELOPMENT AND CALIBRATION OF THE THREE-DIMENSIONAL SITE-SCALE UNSATURATED ZONE MODEL OF YUCCA MOUNTAIN, NEVADA, at 265 (1996) (hereinafter "UNSATURATED ZONE MODEL").

80. J. Fairley & E. Sonnenthal, *Preliminary Conceptual Model of Flow Pathways Based on Cl-36 and Other Environmental Isotopes*, in UNSATURATED ZONE MODEL, at 399 (G.S. Bodvarsson & T.M. Bandurraga eds., 1996).

81. John Bartlett, former Director of U.S. Dept. of Energy's Yucca Program, confirmed that U.S. Dept. of Energy's studies showed that "rates of water infiltration into the mountain were on the order of 100 times higher than had been expected; [and] that water flowed very rapidly through fracture pathways in some of the geologic layers." Affidavit of Dr. John W. Bartlett 22 (Jan. 2002) (hereinafter "Bartlett Aff.").

82. Letter from Bob Miller, Governor of the State of Nevada, to Bill Richardson, Secretary of Energy 2 (Dec. 4, 1998) (on file with author).

percent of all water moving through the repository would reach the water table in less than 1,000 years, but concluded that "additional study [was] warranted" before the site could be disqualified.[83] Yet those additional studies presented only more bad news. A 1999 repository "performance assessment" by DOE showed that the geologic setting at Yucca Mountain contributed almost nothing to the repository's total waste isolation capabilities.[84] That is, DOE's model of the repository "system" showed almost total reliance on engineered barriers—barriers yet to be fully designed.[85] Another DOE performance analysis in 2000 told a similarly bleak story: if engineered barriers failed, the natural barriers would permit a dose rate more than 666 times the EPA limit within the 10,000-year compliance period.[86] A 2001 analysis also showed that if engineered barriers failed, the dose at the site boundary was projected to be more than six times the EPA limit at only 1,000 years. By the 3,000-year mark, the expected dose would rise to 67 times the EPA limit.[87]

E. If at First You Don't Succeed . . . Change the Rules

As it became clear that the Yucca Mountain site could not meet the requirements of the NWPA or the regulations three agencies had promulgated pursuant to that statute, DOE adopted a new strategy: change the site suitability rules, but only with respect to Yucca Mountain. Accordingly, DOE began intensively lobbying the NRC and the EPA to change their respective Yucca Mountain rules to focus on "system" performance analysis in which there would be no separate standards for the component parts of that "system."[88] In doing so, the DOE sought to allow the

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83. Letter from Bill Richardson, Secretary of Energy, to Bob Miller, Governor of the State of Nevada (Dec. 18, 1998) (on file with author).

84. Dennis C. Richardson, U.S. Dept. of Energy Office of Civilian Radioactive Waste Management, Postclosure Defense in Depth in the Design Selection Process, Presentation Before the Nuclear Waste Technical Review Board Panel for the Repository, at 18 (Jan. 25, 1999).

85. *See* Bartlett Aff., *supra* note 82, at ¶ 30. The Department of Energy conceded to the Nuclear Waste Technical Review Board that Yucca's natural barriers would be ineffective to protect against uncertainties in the performance of its engineered barriers, and that "defense-in-depth" could only exist only by stacking one man-made barrier onto another, since geologic factors could make no significant contribution. *See* Dennis C. Richardson, Dept. of Energy Office of Civilian Radioactive Waste Management, Barrier Neutralization Analyses, Presentation to DOE/NRC Technical Exchange: Total System Performance Assessments – Site Recommendation Briefing (Jan. 23, 2001) (hereinafter "*Barrier Neutralization Analyses*").

86. TRW Environmental Safety Systems, Inc., Repository Safety Strategy: Plan to Prepare the Postclosure Safety Case to Support Yucca Mountain Site Recommendation and Licensing Considerations, at E-11 (Jan. 2000).

87. *Barrier Neutralization Analyses, supra* note 85, at 17.

88. *See* Daniel A. Dreyfus, Director, U.S. Dept. of Energy Office of Civilian Radioactive Waste Management, Status of the Civilian Radioactive Waste Management Program, Presenta-

very thing it had said should not be done in 1984: the masking of the deficiencies of the site through reliance on engineered barriers. DOE clearly abandoned any effort to find the right site, which it now called "a false target."[89] DOE wanted to be sure that the Yucca Mountain site could meet any standard that was established, whether or not the physical attributes of the site effectively isolated radioactive waste. DOE went so far as to caution both NRC and EPA that, in formulating new rules, "[p]romulgating a standard that cannot be implemented may result in the *de facto* rejection of the Yucca Mountain site . . . ."[90]

DOE's maneuver to change the rules for Yucca Mountain entered its penultimate phase in 1999, when it published proposed amendments to its repository guidelines, Part 960, announcing a new Part 963 *applicable only* to Yucca Mountain. Part 960 was to be revised to limit its application only to *other* potential repository sites.[91] The new Part 963 established new "site suitability criteria" for *Yucca alone*, abandoning each of the geologic and hydrologic criteria of the NWPA and all qualifying and disqualifying site features. Instead, Part 963 would require DOE to meet just a single qualifying criterion—that a total system performance assessment of the entire repository "system" would demonstrate compliance with the EPA dose limit for the EPA's regulatory compliance period, and thus the repository could ostensibly get an NRC construction permit.[92]

Having lobbied NRC and EPA for three years to change their rules

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tion Before the U.S. Nuclear Regulatory Comm'n, at 4-6 (Jan. 30, 1996) ("Dreyfus Presentation"); Testimony of Lake Barrett, U.S. Dept. of Energy Office of Civilian Radioactive Waste Management, Before the U.S. Nuclear Waste Technical Review Board, at 16 (April 30, 1996); Testimony of Stephan J. Brocum, Assist. Manager for Suitability and Licensing, Yucca Mountain Site Characterization Project Office, Before the NRC Advisory Committee on Nuclear Waste, at 332, and supporting power point slides (June 26, 1996); Testimony of Stephan J. Brocum, Assist. Manager for Suitability and Licensing, Yucca Mountain Site Characterization Project Office, Before the Nuclear Waste Technical Review Board, at 42 (Oct. 9, 1996); Stephan J. Brocum, Assist. Manager for Suitability and Licensing, Yucca Mountain Site Characterization Project Office, Program Overview to License Application, Presentation Before the Nuclear Waste Technical Review Board, at 10 (Oct 9-10, 1996); Lake Barrett, U.S. Dept. of Energy Office of Civilian Radioactive Waste Management, Status of the Civilian Radioactive Waste Management Program, Presentation Before the Nuclear Waste Technical Review Board, at 6 (Oct. 22, 1997).

89. Testimony of Russ Dyer, U.S. Dept. of Energy Office of Civilian Radioactive Waste Management, Before the U.S. Nuclear Waste Technical Review Board, at 152 (April 30, 1996).

90. Dreyfus Presentation, *supra* note 89, at 16. *See also* Stephan J. Brocum, Assist. Manager for Suitability and Licensing, Yucca Mountain Site Characterization Project Office, DOE Perspective on Time Frame of Compliance, Presentation Before the Advisory Committee on Nuclear Waste, at 3-9 (March. 27, 1996).

91. 64 Fed. Reg. 67,054-55 (1999).

92. 64 Fed. Reg. at 67,066-70 (1999).

to a system-based regime that would obscure the distinctive roles of natural and engineered barriers, DOE now blamed the abandonment of Part 960 and the promulgation of Part 963 on the rule changes enacted by those agencies.[93] This was especially ironic given that EPA had earlier objected to DOE's abandonment of Part 960, saying that a "major reason" for the move was DOE's discovery of "significantly faster water flow" than its regulations allowed.[94] According to the EPA, "the waste isolation capability of the natural features of the Yucca Mountain site is at present highly uncertain and largely unassessed."[95] Moreover, the "total-system approach proposed by the DOE could be viewed as masking this uncertainty and the potentially insufficient waste isolation capability of site features if the contributions and uncertainties of the natural and engineered barriers are not individually assessed."[96] The NRC and the EPA had finally relented on changes, largely on the premise that it was solely *DOE*'s statutory role to determine site suitability, not NRC's or EPA's.[97]

DOE's final Part 963 guidelines, applicable only to Yucca Mountain, were published in November 2001 and became effective a month later.[98] By removing from the site selection analysis any independent reliance upon the capabilities of the site's natural barriers to isolate waste, DOE's Yucca Mountain guidelines were "site-specific" only in the narrow sense that they technically applied solely to Yucca Mountain. As a substantive matter, the guidelines rendered the physical characteristics of the Yucca Mountain site irrelevant. At the same time that it adopted new guidelines applicable only to Yucca Mountain, DOE also maintained its earlier site suitability/selection guidelines, which continued to adhere to the NWPA's commitment to primary geologic isolation, for all other potential repository sites. Thus, the federal government established two sets of rules: one dramatically watered-down set for the site in Nevada and one set for sites in any other state.

93. 64 Fed. Reg. at 67,068-72 (1999); C. Kouts, DOE Office of Civilian Waste Management, *Proposed Yucca Mountain Site Suitability Guidelines, 10 CFR 963*, Presentation to Affected Units of Government Meeting, at 3 (Jan. 27, 2000); 66 Fed. Reg. 57,298-99 (2001).

94. General Comments on the Proposed Amendments to 10 CFR Part 960, at 2, *enclosure to* Letter from E. Ramona Trovata, Director, EPA Office of Radiation and Indoor Air, to April V. Gil, DOE Office of Civilian Radioactive Waste Management (March 17, 1997).

95. *Id.* at 3.

96. *Id.*

97. *See, e.g.*, Transcript, NRC Advisory Committee on Nuclear Waste, 90th Meeting, at 99 (March 20, 1997) (stating that it "is their call to make").

98. 66 Fed. Reg. 57,298 (Nov. 14, 2001).

F. Yucca is Selected

On February 14, 2002, barely two months after Part 963 became effective, the Secretary of Energy issued to President George W. Bush a Site Recommendation for Yucca Mountain, saying the "site is scientifically and technically suitable for development of a repository."[99] One day later, President Bush, in a letter to Congress, approved the recommendation. Sixty days later, Nevada's governor submitted to Congress a formal notice of disapproval of the site designation. Congress then proceeded to pass a Joint Resolution overriding the notice of disapproval, which the President signed on July 23, 2002.[100] With that, DOE was both entitled and required to submit a License Application to NRC within ninety days.[101] DOE failed to do so, although it now insists that it will submit an application in December 2004.

II. THE LITIGATION

Now the second strand of the story: the one that more directly involves constitutional issues. The NWPA provides for review in the courts of appeals of "any final decision or action" of the President, the Secretary of Energy, or the NRC taken under the NWPA.[102] Nevada brought a series of petitions for review in the D.C. Circuit challenging the lawfulness of various acts along the way to the selection of the Yucca Mountain site, including the new regulations of DOE, EPA, and NRC; the Secretary of Energy's decision to recommend the site to the President; DOE's Environmental Impact Statement; and the President's decision to recommend the site to Congress.[103] One of these cases is the subject here: Nevada's constitutional challenge to the Joint Resolution by which Congress overrode Nevada's disapproval of the selection of Yucca Mountain as the repository site.[104] All these cases were consolidated and argued *en masse* before the D.C. Circuit on January 14, 2004.

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99. RECOMMENDATION BY THE SECRETARY OF ENERGY REGARDING THE SUITABILITY OF THE YUCCA MOUNTAIN SITE FOR A REPOSITORY UNDER THE NUCLEAR WASTE POLICY ACT OF 1982, at 45 (Feb. 14, 2002) (hereinafter "SITE SUITABILITY RECOMMENDATION"), *available at* http://www.ocrwm.doe.gov/ymp/sr/sar.pdf.

100. *See* Pub. L. No. 107-200, 116 Stat. 735 (2002) (codified at 42 U.S.C. § 10135 (Supp. IV 2004)).

101. *See* 42 U.S.C. § 10134(b) (2000).

102. 42 U.S.C. § 10139(a) (2000).

103. *See NEI*, 373 F.3d at 1261-62.

104. Pub. L. No. 107-200, 116 Stat. 735 (2002).

A. The Constitutional Case: An Overview

Nevada's constitutional challenge to the Joint Resolution rests on a straightforward proposition: the constitutional status of the states as sovereigns entitled to equal dignity and respect requires that Congress exercise its legislative power over the states on the basis of generally applicable, facially neutral criteria and prevents the national government from imposing arbitrary burdens upon particular states. By arbitrarily singling out Nevada to bear the burden of disposing of the nation's nuclear waste (leaving Nevada politically isolated and powerless), the Joint Resolution operates in derogation of Nevada's sovereignty and exceeds the authority granted to the national government under the federal system of government established by the United States Constitution.

Nevada's argument rests on three factual premises. First, that Congress, in the NWPA, adopted the judgment of the scientific community that geologic isolation was critical to the safe, permanent disposal of nuclear waste. Second, that the national government has in fact concluded that Yucca Mountain does not and cannot meet the statutory standard of primary geologic isolation. And, third, that the national government has nevertheless decided to abandon the only neutral standards for safe disposal it had established, forcing Nevada to bear the burden of disposing of this waste.

The difficulty in fashioning this argument was that no constitutional text directly addresses the question at issue. Accordingly we knew that our argument "must be sought in historical understanding and practice, in the structure of the Constitution, and in the jurisprudence of th[e Supreme] Court."[105] Moreover, a body of Supreme Court decisions over the last ten years or so have spurred significant developments in the law of federalism and reinvigorated the practical implications of state sovereignty. The principles animating these decisions, and not their precise holdings, provided the building blocks for Nevada's argument.

B. The Eleventh Amendment

Much of the recent development of the jurisprudence of federalism has involved the Eleventh Amendment, and so those cases were logically the first body of precedent to which we turned. On a first examination, one would not think the Eleventh Amendment would offer much help. The amendment provides that the "Judicial power of the United States shall not be construed to extend to any suit in law or equity, commenced

105. Printz v. United States, 521 U.S. 898, 905 (1997).

and prosecuted against one of the United States by Citizens of another State, or by Citizens or Subjects of any Foreign State."[106] Neither the NWPA, nor our real target, the Joint Resolution, purported to create a cause of action against Nevada or to bring the "judicial power" of the United States to bear against Nevada.

Yet an examination of Eleventh Amendment cases shows a consistent analytical approach that disregards the actual text of the Eleventh Amendment in favor of reliance on principles of sovereignty and on the structure of federalism imbedded in the Constitution. This approach is not a contemporary innovation. For example, in the early part of the last century, the Supreme Court rejected Monaco's effort to sue Mississippi on bonds that the state had issued, holding it to be "manifest[ ]" that

> we cannot rest with a mere literal application of the words of § 2 of Article III, or assume that the letter of the Eleventh Amendment exhausts the restrictions upon suits against non-consenting States. Behind the words of the constitutional provisions are postulates which limit and control. There is the . . . postulate that States of the Union, still possessing attributes of sovereignty, shall be immune from suits, without their consent, save where there has been "a surrender of this immunity in the plan of the convention."[107]

The appearance of this method—going "behind the words of the constitutional provisions" to find "postulates which limit and control"—in modern federalism precedents was provoked, oddly enough, by a dispute over Indian gambling in Florida. When the Seminole Indian Tribe sued Florida to compel the state's compliance with the federal Indian Gaming Regulatory Act,[108] the Court used the Eleventh Amendment as the ground for its decision holding that Congress lacks power under Article I to abrogate the states' sovereign immunity from suits commenced or prosecuted in the federal courts. The Court frankly recognized that "the text of the Amendment would appear to restrict only the Article III diversity jurisdiction of the federal courts."[109] Nevertheless, the Court continued,

> we have understood the Eleventh Amendment to stand not so much for what it says, but for the presupposition . . . which it confirms." That presupposition, first observed over a century ago in *Hans* v. *Louisiana,* has two parts: first, that each State is a sovereign entity in

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106. U.S. CONST. amend. XI.

107. Principality of Monaco v. Mississippi, 292 U.S. 313, 322-323 (1934) (quoting THE FEDERALIST No. 81 (Alexander Hamilton)).

108. Seminole Tribe of Fla. v. Florida, 517 U.S. 44 (1996).

109. *Id.* at 54.

> our federal system; and second, that "it is inherent in the nature of sovereignty not to be amenable to the suit of an individual without its consent.[110]

Three years later, in *Alden v. Maine*,[111] the Court took the opportunity of a lawsuit by state probation officers against their employer, the state of Maine, for alleged violations of the Fair Labor Standards Act, to stretch the Eleventh Amendment's limitation on the reach of federal judicial power out of the context of federal jurisdiction altogether. Here again, the Court turned to fundamental attributes of sovereignty to hold that Congress cannot make the States liable to private suit even in their own state courts, despite the fact that the text of the Eleventh Amendment restricts only *federal* court jurisdiction.

To the *Alden* Court, the actual parameters of the constitutional text posed no difficulty. "To rest on the words of the Amendment alone would be to engage in the type of ahistorical literalism we have rejected in interpreting the scope of the States' sovereign immunity since the discredited decision in *Chisholm*."[112] Rather, the analysis must proceed from "'history and experience, and the established order of things,' rather than 'adhering to the mere letter' of the Eleventh Amendment, in determining the scope of the States' constitutional immunity from suit."[113] The Court justified this approach by pointing out that

> sovereign immunity derives not from the Eleventh Amendment but from the structure of the original Constitution itself. *See, e.g., Idaho* v. *Coeur d' Alene Tribe of Idaho,* 521 U.S. 261, 267-268 (1997) (acknowledging "the broader concept of immunity, implicit in the Constitution, which we have regarded the Eleventh Amendment as evidencing and exemplifying"); *Seminole Tribe, supra,* at 55-56; *Pennhurst State School and Hospital* v. *Halderman,* 465 U.S. 89, 98-99 (1984); *Ex parte New York, supra,* at 497. The Eleventh Amendment confirmed rather than established sovereign immunity as a constitutional principle; it follows that the scope of the States' immunity from suit is demarcated not by the text of the Amendment alone but by *fundamental postulates implicit in the constitutional design*.[114]

Under the *Alden* Court's reasoning, the Eleventh Amendment was not even necessary to preserve state sovereign immunity. As the Court explained:

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110. *Id.* (citations omitted).
111. 527 U.S. 706 (1999).
112. *Id.* at 730.
113. *Id.* at 727 (citations omitted).
114. *Id.* at 728-29 (emphasis added).

> While the constitutional principle of sovereign immunity does pose a bar to federal jurisdiction over suits against nonconsenting States, this is not the only structural basis of sovereign immunity implicit in the constitutional design. Rather, "there is also the postulate that States of the Union, still possessing attributes of sovereignty, shall be immune from suits, without their consent, save where there has been 'a surrender of this immunity in the plan of the convention.'" This *separate and distinct structural principle* is not directly related to the scope of the judicial power established by Article III, but *inheres in the system of federalism established by the Constitution.* In exercising its Article I powers Congress may subject the States to private suits in their own courts only if there is "compelling evidence" that the States were required to surrender this power to Congress pursuant to the constitutional design.[115]

As the reasoning of these sovereign immunity cases unfolds one sees that, to the Court's mind, they are not so much about immunity as about the sovereignty from which that immunity arises. The Court affirmed this view just two years ago, in *Federal Maritime Commission v. South Carolina State Ports Authority*,[116] noting that the sovereign immunity doctrine's "central purpose is to 'accord the States the respect owed them as' joint sovereigns."[117] The Court emphasized, moreover, that "[d]ual sovereignty is a defining feature of our Nation's constitutional blueprint."[118] What Madison wrote in 1787 has lost none of its vitality in our constitutional order: the "States thus retain 'a residuary and inviolable sovereignty.' They are not relegated to the role of mere provinces or political corporations, but retain the dignity, though not the full authority, of sovereignty."[119]

The implications of this precedent for our constitutional argument in the Yucca Mountain case are profound. Our system of federalism not only limits *what* Congress may do, but also limits *how* Congress may do it.

> When Congress legislates in matters affecting the States, it may not treat these sovereign entities as mere prefectures or corporations.

115. *Id.* at 730-31 (emphases added; citations omitted).

116. 535 U.S. 743, 760 (2002) (holding that state sovereign immunity bars the Federal Maritime Commission from "adjudicating a private party's complaint that a state-run port has violated the Shipping Act of 1984").

117. *Id.* at 765.

118. *Id.* at 751.

119. Alden v. Maine, 527 U.S. 706, 715 (quoting THE FEDERALIST No. 39 (James Madison)); *see also* Federal Mar. Comm'n v. South Carolina State Ports Auth., 535 U.S. at 743, 751 (2002) ("States, upon ratification of the Constitution, did not consent to become mere appendages of the Federal Government.").

> Congress must accord States the esteem due to them as joint participants in a federal system, one beginning with the premise of sovereignty in both the central Government and the separate States. Congress has ample means to ensure compliance with valid federal laws, but it must respect the sovereignty of the States.[120]

It follows that although Congress may establish a national nuclear waste repository, it may not run roughshod over Nevada's sovereign dignity in the process.

C. *The "Commandeering" Cases*

In *New York* v. *United States*[121] and *Printz* v. *United States*,[122] the Supreme Court held that Congress cannot "commandeer" the states by requiring them to enact federal policies into law or to administer federal laws. *New York v. United States* has interesting parallels with the Yucca Mountain controversy as it arose from the effort of Congress, in the Low-Level Radioactive Waste Policy Amendments Act of 1985, to encourage the states to provide for the disposal of low-level radioactive waste generated within their borders. Congress adopted three devices to provide this "encouragement." Monetary incentives and "access incentives" (that is, barring states that had not taken any action to develop their own disposal facilities from access to out-of-state disposal sites) passed constitutional muster.[123] However, the third device required states that had not provided for disposal of in-state low-level waste to "take title" to that waste or to regulate such waste according to congressional directives. This went too far: "[w]hether one views the take title provision as lying outside Congress's enumerated powers, or as infringing upon the core of state sovereignty reserved by the Tenth Amendment, the provision is inconsistent with the federal structure of our Government established by the Constitution."[124]

In *Printz*, two local law enforcement officers, one from Montana and one from Arizona, objected to "being pressed into federal service" by provisions of the Brady Handgun Violence Protection Act that imposed an obligation on state law enforcement officers to conduct background checks on prospective purchasers of handguns.[125] The Court found these objections to be well-taken and held those provisions to be

120. *Alden*, 527 U.S. at 758.
121. 505 U.S. 144 (1992).
122. 521 U.S. 898 (1997).
123. 505 U.S. at 171-74.
124. *Id.* at 177.
125. 521 U.S. at 905.

unconstitutional. Following its reasoning from *New York v. United States*, the Court concluded that both commands to the states to address particular problems and commands to the states' officers to enforce a federal program "are fundamentally incompatible with our constitutional system of dual sovereignty."[126]

Here again, the precise holdings of these cases are not implicated in the Yucca Mountain matter. The Joint Resolution does not attempt to legislate for Nevada as a state, or to commandeer state instrumentalities or officers to implement federal policies.[127] Yet the rationale for these holdings is relevant, for it is predicated on a vision of the dignity and role of states in a federal system. In *Printz*, for example, the Court explained that its holding was compelled by the fact that "[p]reservation of the States as independent political entities" was "the price of union."[128] Although the Court noted in *New York v. United States* that this "inviolable sovereignty" was "reserved explicitly to the States by the Tenth Amendment,"[129] the Tenth Amendment hardly sets out the contours of that sovereignty in a handy way for adjudicating particular cases, much less explicitly drawing a clear perimeter around the permissible actions of the national government.[130]

On the other hand, the majority in *Printz* admitted, "[b]ecause there is no constitutional text speaking to this precise question, the answer to the [States'] challenge must be sought in historical understanding and practice, in the structure of the Constitution, and in the jurisprudence of this Court."[131] As a result of that search, the *Printz* Court found the Constitution's system of "dual sovereignty" and the states' "residuary and inviolable sovereignty" to be

> reflected throughout the Constitution's text, *Lane County* v. *Oregon,* 74 U.S. 71 (1869); *Texas* v. *White,* 74 U.S. 700, 725 (1869), including (to mention only a few examples) the prohibition on any involuntary reduction or combination of a State's territory, Art. IV, § 3; the Judicial Power Clause, Art. III, § 2, and the Privileges and Immunities Clause, Art. IV, § 2, which speak of the "Citizens" of the States; the amendment provision, Article V, which requires the votes of

126. *Id.* at 935.

127. *See, e.g.*, Nevada v. DOE, 133 F.3d 1201, 1207 (9th Cir. 1998) ("Nevada has not been directly compelled to enact or enforce a federal regulatory program. . . . The NWPA itself . . . is implemented entirely by federal government agencies.").

128. 521 U.S. at 919.

129. 505 U.S. at 188.

130. *See* U.S. CONST. amend. X ("The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people.").

131. 521 U.S. at 905.

> three-fourths of the States to amend the Constitution; and the Guarantee Clause, Art. IV, § 4, which "presupposes the continued existence of the states and . . . those means and instrumentalities which are the creation of their sovereign and reserved rights," *Helvering v. Gerhardt,* 304 U.S. 405, 414-415 (1938). Residual state sovereignty was also implicit, of course, in the Constitution's conferral upon Congress of not all governmental powers, but only discrete, enumerated ones, Art. I, § 8, which implication was rendered express by the Tenth Amendment's assertion that "the powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people."[132]

In the commandeering cases, then, the Supreme Court turned to the first principles of the federal system, which it derived from reviewing the entire structure set forth in the Constitution, in order to make the "residuary and inviolable sovereignty" of the states something more than an evanescent platitude. As the Court observed, "[s]ome truths are so basic that, like the air around us, they are easily overlooked."[133] Those basic truths form the bedrock of Nevada's constitutional complaint against the siting of the nation's nuclear waste repository at Yucca Mountain.

D. *Equal Protection as a Component of State Sovereignty*

Respecting Nevada's residual sovereignty is obviously a good thing, but further refinement of that general proposition is needed to establish a specific constitutional objection to the siting of a nuclear waste repository in the state. If there is to be a viable constitutional claim grounded on some affront to Nevada's sovereignty, it logically must involve some notion that Nevada has not been treated with a dignity equal to that of her sister states; that is, that the dump truly has been dumped on Nevada.

Not only does such equality of respect among the states seem logically entailed by their equal stature as sovereigns, several provisions of the Constitution offer cases in point for this equal treatment. The Port Preference Clause, for example, provides that "[n]o Preference shall be given . . . to the Ports of one State over those of another."[134] Similarly, the Uniformity Clause mandates that "Duties, Imposts and Excises shall be Uniform throughout the United States."[135] Obviously, neither the Joint Resolution nor the NWPA has anything to do with ports, duties, imposts or excise taxes. But these provisions arose out of the Framers'

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132. *Id.* at 919.
133. New York v. United States, 505 U.S. 144, 187 (1992).
134. U.S. CONST. art. I, § 9, cl. 6.
135. U.S. CONST. art. I, § 8, cl. 1.

recognition that the broad commerce power delegated to the national government created a risk that the "National Government would use its power over commerce to the disadvantage of particular States."[136]

When the Constitutional Convention's Committee of Detail released its formulation of the Commerce Clause in the August 6, 1787 draft, Delaware delegate John Dickinson noted in the margin, next to the Commerce Clause, "no Preference or Advantage to be given to any persons or place—Laws to be equal."[137] So great was the concern over discriminatory congressional employment of the commerce power that it appears likely that the Constitution would not have made it out of the Philadelphia convention, let alone have been ratified, if these guarantees of equal treatment had not been included. In the words of one delegate, "I do not hazard much in saying, that the present Constitution had never been adopted without those preliminary guards in it."[138] As Justice Story concluded,

> [i]f this provision, as to uniformity of duties, had been omitted, although the power might never have been abused to the injury of the feebler States of the Union, (a presumption which history does not justify us in deeming quite safe or certain) yet it would, of itself, have been sufficient to demolish, in a practical sense, the value of most of the other restrictive clauses in the Constitution.[139]

These widespread concerns led to the adoption of the Port Preference and Uniformity Clauses, both barring the national government from discriminating against any particular state. These limitations "were intended to allay . . . the fear that Congress might discriminate against certain of the States."[140] "The clear and obvious intention of the articles mentioned was that Congress might have no power of imposing unequal burdens; that it might not be in their power to gratify one part of the Union by oppressing another."[141]

Thus the Uniformity and Port Preference Clauses make explicit an equality principle that, out of respect for state sovereignty, must be un-

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136. United States v. Ptasynski, 462 U.S. 74, 81 (1983).

137. 1 THE RECORDS OF THE FEDERAL CONVENTION OF 1787 209 (Max Farrand, ed., rev. ed. 1937) [hereinafter FARRAND RECORDS]. *See also* 2 FARRAND RECORDS 211 (James McHenry); *id.* at 637 n.21, 639-40 (George Mason); 3 FARRAND RECORDS 333 (Alexander Hamilton); CHARLES WARREN, THE MAKING OF THE CONSTITUTION 575-76, 588 (1928).

138. 3 FARRAND RECORDS, *supra* note 137, at 366 (Hugh Williamson).

139. JOSEPH STORY, COMMENTARIES ON THE CONSTITUTION OF THE UNITED STATES § 479 (1833).

140. WARREN, *supra* note 137, at 588.

141. 3 FARRAND RECORDS, *supra* note 137, at 366 (Hugh Williamson). *See also* 2 FARRAND RECORDS at 417-18 (James Madison); *id.* at 420 (James McHenry).

derstood as implicit in the Commerce Clause insofar as Congress applies the commerce power to the States. Since the Commerce Clause is one root of the national government's power to establish a national nuclear waste repository, this limitation has an important and direct role in Nevada's argument against the Yucca Mountain facility.

Not to be overlooked is the Constitution's ban, for both Congress and the state legislatures, on bills of attainder.[142] The term "bill of attainder" originally applied to legislative enactments decreeing death for named individuals (or designated groups) for high crimes, usually treason. The targets were "attainted" and therefore their property could not be inherited, which usually meant that the crown got the property. Bills of attainder were, accordingly, a popular means for raising revenue as well as getting rid of those whom the state feared. Over time the term came to refer to, and to forbid, all forms of legislative trial and punishment, because legislative trials were seen as violating the separation of powers. Legislatures were not to declare a named individual guilty of a crime, but rather were to enact laws that described criminal offenses in general terms and to leave to the courts the task of applying those general laws in individual cases.[143]

The Bill of Attainder Clause protects only persons, not states, and states lack standing to invoke the clause against the federal government on behalf of their citizens.[144] Therefore, the clause cannot be directly invoked by Nevada in making its case against the Yucca Mountain repository. However, the principle animating the clause does shed light on the constitutional wrong being inflicted on Nevada. After all, the ban on bills of attainder confirms the central importance of *generality* as a safeguard for ensuring just laws.[145] A bill of attainder acts by *naming* those who are targets of legislation, by *specifying* those who are to be singled out for special treatment under a specially enacted law. Proper laws describe *general characteristics* of the subject of legislation and set forth *generally applicable rules* that apply to all those who fit the legislative description.[146] Chief Justice Marshall identified the constitutional vice of a bill of attainder as being a violation of the principle that the legisla-

142. *See* U.S. CONST. art. I, § 9, cl. 3; art. I, § 10, cl. 1.

143. *See generally* LAWRENCE TRIBE, AMERICAN CONSTITUTIONAL LAW §§ 10-4 to 10-6 (2d ed. 1988). Montesquieu located the origins of the bill of attainder in the Roman practice of enacting *privilegia*, or private laws, against specific parties. He noted that "Cicero was for having them abolished, *because the force of a law consists in its being made for the whole community*." MONTESQUIEU, THE SPIRIT OF THE LAWS, bk. 12, ch. 19 (1748), *reprinted in* 3 THE FOUNDERS' CONSTITUTION 343 (Philip B. Kurkland & Ralph Lerner, eds., 1987) (emphasis added).

144. *See* South Carolina v. Katzenbach, 383 U.S. 301, 324 (1966).

145. *See* TRIBE, *supra* note 143, at 641.

146. *See id.* at 646.

ture should "prescribe general rules."[147]

Modern cases repeatedly emphasize this core principle: Congress may not impose legal burdens except "by rules of general applicability."[148] Indeed, a law that "designates" the parties who will bear its burdens, instead of "set[ting] forth a generally applicable rule,"[149] cannot properly be dignified with the title of "law." The very definition of a "law" is that it applies generally; it prescribes not a result in one case but "a rule" for all cases.[150] Yet, what is the Joint Resolution, if not an enactment that prescribes a result in only one case? Isn't the Joint Resolution a purported "law" that singles out Nevada for the application of a discriminatory nuclear waste disposal site regulation that will govern only Yucca Mountain and not any other site anywhere in the other forty-nine States?

Interestingly, the Supreme Court's Tenth Amendment jurisprudence also reflects this principle. The Court has held that a state may invoke judicial enforcement of the Tenth Amendment's protection of state sovereignty if it can demonstrate "defects in the national process."[151] The Court's example of such a "defect" involved showing that the state "*was singled out in a way that left it politically isolated and powerless.*"[152] This is clearly a variation on the principle driving the ban on bills of attainder, a principle that now can be seen as part of Tenth Amendment doctrine to trigger judicial intervention to protect state sovereignty. The Tenth Amendment will be discussed further in the next section.

Some well-recognized limits on the national government's ability to discriminate among the states are found not in particular clauses of the Constitution, but in the federal (rather than national) structure of the Union. Such limits arise "from the very nature and objects" of the Union itself.[153] One good example of such limits is found in the "equal footing doctrine," which recognizes that the several states entered the Union "equal in power, dignity and authority," and requires that Congress respect each state's "equality in dignity and power with other States."[154]

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147. Fletcher v. Peck, 10 U.S. 87, 136 (1810).

148. United States v. Brown, 381 U.S. 437, 461 (1965). *See also id.* at 446 (holding that the legislature must "'prescribe general rules'") (quoting *Fletcher v. Peck*); *id.* at 454-55 (holding that a law is permissible only if "Congress was legislating with respect to general characteristics rather than with respect to a specific group of men").

149. *Id.* at 450.

150. *See* W. Johnson, Note to *Satterlee v. Mathewson*, 2 Pet. 380, n. 416 (1829) (discussing Blackstone), *reprinted in* 3 THE FOUNDERS' CONSTITUTION 351 (Philip B. Kurkland & Ralph Lerner, eds., 1987).

151. South Carolina v. Baker, 485 U.S. 505, 512 (1988).

152. *Id.* at 513 (emphasis added).

153. Coyle v. Smith, 221 U.S. 559, 575 (1911) (citation omitted).

154. *Id.* at 567-68.

The "constitutional equality of the States is essential to the harmonious operation of the scheme upon which the Republic was organized. When that equality disappears we may remain a free people, but the Union will not be the Union of the Constitution."[155]

Although the equal footing doctrine is usually implicated in cases dealing with the congressional power to admit states to the Union, it has also arisen in the context of the Commerce Power and the Treaty Power.[156] For example, in *United States v. 43 Gallons of Whiskey*, the Court considered an equal footing challenge to a federal law regulating commerce in liquor.[157] The Court rejected the argument that the law discriminated against Minnesota, finding that it legislated in general terms that applied to particular circumstances wherever they existed, rather than to particular states.[158] The Court concluded: "The principle that Federal jurisdiction must be everywhere the same, under the same circumstances, has not been departed from. The prohibition rests on grounds which, so far from making a distinction between the States, apply to them all alike."[159]

The equal footing doctrine thus embodies an anti-discrimination principle that arises from a broader, generally applicable "constitutional mandate that the States be on an equal footing."[160] This does not mean that Congress may not legislate with respect to differing conditions: "Area, location, geology, and latitude have created great diversity in the economic aspects of the several States. The requirement of equal footing was designed not to wipe out those diversities but to create parity as respects political standing and sovereignty."[161] It is this "parity" in "sovereignty" that mandates that States can be treated differently by Congress only insofar as they are *in fact* different. Different treatment of a given state simply because it is the state named by the national government would be arbitrary and an abuse of the national legislative power. Yet that is exactly what Congress did in the Joint Resolution approving the Yucca Mountain site.

E. The Tenth Amendment: The Foundation of the Argument

Although the principles on which Nevada built its constitutional ar-

155. *Id.* at 580.
156. *See, e.g.*, Mayor of New Orleans v. United States, 35 U.S. 662, 736-37 (1836); United States v. 43 Gallons of Whiskey, 93 U.S. 188, 191, 193-94 (1876).
157. 93 U.S. at 191.
158. *Id.* at 194-95, 197.
159. *Id.* at 197.
160. Baker v. Carr, 369 U.S. 186, 226 n.53 (1962).
161. United States v. Texas, 339 U.S. 707, 716 (1950).

gument against the Yucca Mountain Joint Resolution ultimately are derived from the structure of government created by the Constitution, the jurisprudence of the Tenth Amendment provides the most helpful illumination of that structure. The Tenth Amendment simply states that the "powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people."[162]

The Tenth Amendment can strike one as restating the obvious; what is not given to the new national government is not given to the new national government. For that reason, perhaps, for at least a century, America's leading jurists and constitutional thinkers delighted in belittling the Tenth Amendment. It has been dismissed as "redundant," a "constitutional tranquilizer," or an "empty declaration."[163] Chief Justice Stone no doubt thought he was penning the amendment's epitaph when he wrote that it "states but a truism that all is retained which has not been surrendered."[164] Yet "to diminish the Tenth Amendment as merely 'declaratory' is likewise to vitiate the Supremacy Clause and the Necessary and Proper Clause, for each, Hamilton wrote in No. 33 of the *Federalist*, was merely declaratory."[165]

Moreover, unlike either of those two clauses, the Tenth Amendment is something a little different, a bit more special, because it is *a rule of construction*. Indeed, it is one of only two rules of construction in the entire Constitution, the other being the Ninth Amendment. Consistent with the long-standing disregard of the Tenth Amendment, its very status as a rule of construction has sometimes been a basis for derogating it. Justice Story described it as "a mere affirmation of what, upon any reasoning, is a necessary rule of interpreting the Constitution."[166] But to suggest that the Tenth Amendment is *less* worthy of our attention because it is a rule of construction rather than a substantive "rule of law,"[167] is to get things precisely backward. Rules of construction tell us (judges, legislators, and citizens) *how to read the Constitution*. In such rules the Framers step back from the task of erecting a government and turn to face the camera, as it were. They address posterity directly, tell-

162. U.S. CONST. amend. X.

163. *See* FELIX FRANKFURTER, THE COMMERCE CLAUSE 40 (1937); ALPHEUS THOMAS MASON, THE STATES RIGHTS DEBATE: ANTIFEDERALISM AND THE CONSTITUTION 5, 190 (1967).

164. United States v. Darby, 312 U.S. 100, 124 (1941).

165. RAOUL BERGER, FEDERALISM: THE FOUNDER'S DESIGN 81 (1987). *See also* THE FEDERALIST NO. 33, at 204-05 (Alexander Hamilton) (Jacob E. Cooke ed., 1961).

166. JOSEPH STORY, 3 COMMENTARIES ON THE CONSTITUTION OF THE UNITED STATES 752 (1833). *See also* Walter Berns, *The Meaning of the Tenth Amendment*, *in* A NATION OF STATES 126, 131-32 (Robert A.Goldwin ed., 1961).

167. Berns, *supra* note 166, at 131.

ing us that when we sit down to construe the document to decide some controversy we are required to read it in a certain way. The rules of construction are the owner's manual to the Constitution, and few passages in a founding charter could be more important.

As a consequence, despite its scholarly and judicial detractors, the Tenth Amendment has become, over time, much more than a simple reservation to the states of non-delegated powers. As the majority in *South Carolina v. Baker* put it, the Tenth Amendment has come to represent, and to serve as shorthand for, "any implied constitutional limitation on Congress's authority to regulate state activities, whether grounded in the Tenth Amendment itself or in principles of federalism derived generally from the Constitution."[168]

In resolving fundamental questions of federalism, the Tenth Amendment requires the Court to consider "the design of the Government and to appreciate the significance of federalism in the whole structure of the Constitution."[169] "The question, always, is whether the exercise of power is consistent with the entire Constitution, a question that can be answered only by taking into account, so far as they are relevant, all of the values to which the Constitution—as interpreted over time—gives expression."[170]

It should come as no surprise that the values of federalism have shaped the constitutional text, resulting in constitutional protections for the states as sovereign entities entitled to equal respect and treatment. After all, the independent existence of the states preceded not only the Constitution, but also the Union. Some of the states individually declared independence from Great Britain (and substituted governance by their own elected officials for the sovereignty of the king) even *before* Congress promulgated the Declaration of Independence. Rhode Island declared independence on May 4, 1776 and announced its intention to "promot[e] confederation" with the "other colonies;" Virginia declared independence on May 15, 1776.[171]

Richard Henry Lee's resolution on independence, passed by the Continental Congress on July 2, 1776, asserted the new status of the sev-

168. 485 U.S. 505, 511 n.5 (1988).

169. United States v. Lopez, 514 U.S. 549, 575 (1995) (Kennedy, J., concurring). *See also* U.S. Term Limits v. Thornton, 514 U.S. 779, 853 (1995) (Thomas, J., dissenting) (Tenth Amendment issues "'depend on a fair construction of the whole [Constitution].'") (quoting McCulloch v. Maryland, 17 U.S. 316, 406 (1819) (alteration in original)).

170. Garcia v. San Antonio Metro. Transit Auth., 469 U.S. 528, 586 (1985) (O'Connor, J., dissenting) (quoting Terrance Sandalow, *Constitutional Interpretation*, 79 MICH. L. REV. 1033, 1055 (1981)).

171. MERRILL JENSEN, THE ARTICLES OF CONFEDERATION 102-03 (1940).

eral former colonies as plural "free and independent *States*."[172] Far from declaring independence as a unified national entity, or establishing a sovereign national government for North America, the congressional resolution called for the representatives of the now-independent states to prepare a "plan of confederation" to be "transmitted to the respective Colonies for their consideration."[173] Pursuant to the formal Declaration of Independence signed two days later, the "States of America" by the authority of the "good People of these Colonies" separated themselves from Great Britain by declaring that they were "Free and Independent states," and that "they have full Power" to do all "Acts and Things which Independent States may of right do."[174]

When the Continental Congress made good on Lee's resolution and proposed a form for the national government, the resulting "articles of Confederation and perpetual Union between the States of New Hampshire, Massachusetts-bay," and so on down the roster, declared that "[e]ach state retains its sovereignty, freedom and independence."[175] On September 13, 1783, the status of the states as individual, independent sovereigns was confirmed by the peace treaty that ended the Revolutionary War. The Treaty of Paris—which is the document that formally recognized the independence of the States—was, like Lee's Resolution, Jefferson's Declaration, and the Articles of Confederation, cast in plural form and filled with references to "the said United States:" "His Brittanic Majesty acknowledges the said United States, viz. New Hampshire, Massachusetts Bay," *et al.*, "to be free sovereign and independent States."[176] Article V of the treaty provided that British subjects were to be free to go to "any of the thirteen United States," thereby signifying that Great Britain was treating with thirteen sovereign States rather than with a single unitary nation.[177]

Having recently fought a revolution to free themselves from distant, centralized authority in London, the states were not about to allow themselves to be subsumed in the undifferentiated, common mass of a new and more powerful national government. The states convened in Philadelphia as free, independent, and equal sovereigns. Madison explained that the "equality" of the States is "no less acceptable to the large than to

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172. HENRY STEELE COMMAGER, DOCUMENTS OF AMERICAN HISTORY 100 (7th ed., 1963) (emphasis added).

173. *Id.*

174. *See* THE DECLARATION OF INDEPENDENCE ¶ 32 (U.S. 1776).

175. ARTICLES OF CONFEDERATION art. II (1781).

176. 1 TREATIES, CONVENTIONS, INTERNATIONAL ACTS, PROTOCOLS AND AGREEMENTS BETWEEN THE UNITED STATES AND OTHER POWERS, 1776-1909, at 587 (William M. Malloy ed., 1910).

177. *Id.*; *see also* RAOUL BERGER, FEDERALISM: THE FOUNDER'S DESIGN 29 (1987).

the small states; since they are not less solicitous to guard by every possible expedient against an improper consolidation of the states into one simple republic."[178] Even James Wilson, the second-most influential of the Framers and among the most nationalist in his thinking, insisted that the federal government, "instead of placing the state governments in jeopardy, is founded on their existence. On this principle, its organization depends; it must stand or fall, as the state governments are secured or ruined."[179] Indeed, Madison emphasized that the Constitution's authority would derive from popular consent "given by the people, not as individuals composing one entire nation, but as composing the distinct and independent States to which they respectively belong."[180] Madison reassured the state ratifying conventions that "[e]ach State, in ratifying the Constitution, is considered to be a sovereign body, independent of all others."[181]

Once in the Union, however, the states were bound by democratic majority rule under the Constitution's terms. Even the Constitution itself can be amended without the consent of any given state.[182] Consequently, "the Constitution, in all its provisions, looks to *an indestructible Union, composed of indestructible States*."[183] It is this proposition that sets out the essential dynamic in our federal Union of sovereign states. *Precisely because* the states are not free to secede from the Union and will be bound by democratically enacted supreme federal law—laws which particular states may oppose—there are implicit limits on how much the national government may invade the sovereign prerogatives of

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178. THE FEDERALIST NO. 62, at 417 (James Madison) (Jacob E. Cooke ed., 1961).

179. James Wilson, *Summation and Final Rebuttal, Speech to the Pennsylvania Ratifying Convention, December 11, 1787*, *reprinted in* 1 THE DEBATE ON THE CONSTITUTION 841 (Bernard Bailyn, ed., 1993).

180. THE FEDERALIST NO. 39, at 254 (James Madison) (Jacob E. Cooke ed., 1961); *see also* 3 THE DEBATES IN THE SEVERAL STATE CONVENTIONS ON THE ADOPTION OF THE FEDERAL CONSTITUTION 94 (J. Elliot 2d ed. 1836) (remarks of James Madison at the Virginia convention).

181. THE FEDERALIST NO. 39, at 254 (James Madison) (Jacob E. Cooke ed., 1961); *see also* THE FEDERALIST NO. 40, at 261 (James Madison) (Jacob E. Cooke ed., 1961) (States are "regarded as distinct and independent sovereigns" by "the Constitution proposed").

> The ultimate source of the Constitution's authority is the consent of the people of each individual State, not the consent of the undifferentiated people of the Nation as a whole. The ratification procedure erected by Article VII makes this point clear. The Constitution took effect once it had been ratified by the people gathered in convention in nine different States. But the Constitution went into effect only "between the States so ratifying the same." It did not bind the people of North Carolina until they had accepted it.

U.S. Term Limits v. Thornton, 514 U.S. 779, 846 (Thomas, J., dissenting).

182. *See* U.S. CONST. amend. V (describing amendment process).

183. Texas v. White, 74 U.S. 700, 725 (1869) (emphasis added); *see also* New York v. United States, 505 U.S. 144, 162 (1992) (quoting Texas v. White).

the states. That is, because the states are "chained" to the Union, there are limits on how much Congress can yank that chain. Thus "the preservation of the States, and the maintenance of their governments, are as much within the design and care of the Constitution as the preservation of the Union and the maintenance of the National government."[184]

Yet recognizing that the sovereignty of the States is to be protected in our constitutional order is to say nothing about *how* that sovereignty is to be protected. In the mid-1980s the Supreme Court, in Tenth Amendment cases such as *Garcia v. San Antonio Metropolitan Transit Authority*[185] and *South Carolina v. Baker,*[186] appeared to drastically curtail the judiciary's power to protect against encroachments on state sovereignty by the federal government.[187] Following the *Garcia* and *Baker* decisions, the conventional wisdom for some time was that the only real limits on congressional exercise of the Commerce Clause power were: (1) the political check provided by the national political process, with its fifty state delegations of representatives and senators in Congress, and (2) what Justice O'Connor memorably described as Congress's "underdeveloped capacity for self-restraint."[188]

But *Garcia* did *not* hold that the *only* restraint on congressional invasion of state sovereignty was the political process; rather, it held that the political process was the "principal and basic limit."[189] The Court expressly disclaimed any broader ruling, explaining that the case did "not require us to identify or define what affirmative limits the constitutional structure might impose on federal action affecting the States under the Commerce Clause."[190] At that point *Garcia* cited *Coyle v. Smith,*[191] which had held that irreducible state sovereignty *does* impose some substantive limits on congressional power.

Four of the five Justices who constituted the *Garcia* majority are no longer on the Court. Since that decision seventeen years ago, a narrow but determined majority of the Court has issued a series of decisions

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184. Texas v. White, 74 U.S. at 725; New York v. United States, 505 U.S. at 162 (quoting Texas v. White).

185. 469 U.S. 528 (1985).

186. 485 U.S. 505 (1988).

187. In *Garcia*, the Court, in a 5-4 decision, overruled its earlier decision in *National League of Cities v. Usery*, 426 U.S. 833 (1976), and rejected a Tenth Amendment challenge to a federal statute imposing minimum wage and overtime pay standards on State governments. In *Baker*, the Court rejected a Tenth Amendment challenge to a provision of the Internal Revenue Code removing a federal income tax exemption for interest earned on certain types of bonds issued by state and local governments.

188. *Garcia*, 469 U.S. at 588 (O'Connor, J., dissenting).

189. *Id.* at 556.

190. *Id.*

191. 221 U.S. 559 (1911).

championing state sovereignty over the legislative prerogatives of Congress.[192] To whatever extent *Garcia* and *Baker* might be read to rigidly foreclose judicial protection of states' prerogatives within the Constitution's federal structure, they no longer appear to be good law.

Certainly, the notion of a flat ban on judicial enforcement of principles of federalism was always deeply problematic. The horizontal axis of the Constitution—the separation of powers into legislative, judicial, and executive bailiwicks—is amenable to, and entitled to, judicial policing. Why shouldn't the vertical axis—federalism—be as well? Nobody at either end of the political spectrum would insist that the Constitution's structural and textual separation of powers must be enforced exclusively by democratic processes – must, in effect, be treated as a political question off-limits to the judiciary. It is therefore hard to understand why such a rule should govern the equally important structural rules of federalism.

Again, the Tenth Amendment is a rule for construing the Constitution. To whom is that rule addressed, if not to the courts, which are charged with expounding the Constitution?[193] "The States' role in our system of government is a matter of constitutional law, not of legislative grace,"[194] and therefore the boundaries between federal and state sovereignty must be judicially policed, just like the boundaries between the legislative and executive branches. "If federalism so conceived and so carefully cultivated by the Framers of our Constitution is to remain meaningful, this Court cannot abdicate its constitutional responsibility to oversee the Federal Government's compliance with its duty to respect the legitimate interests of the States."[195]

States can no more be relegated to exclusively political safeguards for fundamental states' rights than individuals can be relegated to the political process for the protection of their rights. The fundamental flaw in the *Garcia* majority's reasoning is that its "political process" argument applies equally to individuals as to states, and that reveals its fundamental fallacy. As Justice Powell explained in *Garcia*, "One can hardly imagine this Court saying that because Congress is composed of individuals, individual rights guaranteed by the Bill of Rights are amply pro-

192. *See* Federal Maritime Comm'n v. S.C. State Ports Auth., 535 U.S. 743 (2002); United States v. Morrison, 529 U.S. 598 (2000); Alden v. Maine, 527 U.S. 706 (1999); Printz v. United States, 521 U.S. 898 (1997); Seminole Tribe of Fla. v. Florida, 517 U.S. 44 (1996); United States v. Lopez, 514 U.S. 549 (1995); New York v. United States, 505 U.S. 144 (1992).

193. *Cf.* Marbury v. Madison, 5 U.S. 137, 177 (1803); Garcia v. San Antonio Metro. Transit Auth., 469 U.S. 528, 567 (1985) (Powell, J., dissenting).

194. *Garcia*, 469 U.S. at 567 (Powell, J., dissenting).

195. *Id.* at 581 (O'Connor, J., dissenting).

tected by the political process. Yet, the position adopted today is indistinguishable in principle. The Tenth Amendment also is an essential part of the Bill of Rights."[196]

The notion that the Bill of Rights was about *individual* rights—a notion clearly animating the *Garcia* majority—while perhaps a function of the Court's focus on individual rights in the last half of the twentieth century, is profoundly ahistorical. The Tenth Amendment was, if anything, the *most important* part of the Bill of Rights with respect to the vital, practical issue of securing ratification of the Constitution. Eight of the original eleven States that ratified the Constitution[197] did so only after proposing amendments, and every one of those States included some version of what ultimately became the Tenth Amendment.[198] Indeed, the Tenth Amendment was the *only* amendment proposed by every single state ratifying convention that offered amendments.[199] The leading proponents of a bill of rights consistently "linked the project to an express reservation of states' rights."[200] Surely the states (and their people) are just as entitled to judicial enforcement of the Tenth Amendment as individuals are to the protections of the Fourth Amendment.

Notwithstanding the flaws in *Garcia's* reasoning, outright reversal of that decision is not necessary to forge a constitutional argument for Nevada on Tenth Amendment grounds. Again, *Garcia* did not purport to define every limit imposed by the structure of the Constitution on federal action affecting the states. As the Court acknowledged three years later in *South Carolina v. Baker,* "*Garcia* left open the possibility that some extraordinary defects in the national political process might render congressional regulation of state activities invalid under the Tenth Amendment."[201] Note well the scope and seriousness of the opening left by the Court: defects in the political process do not merely render congressional legislation *subject to judicial challenge* under the Tenth Amendment, they "render congressional regulation of state activities *invalid* under the Tenth Amendment."[202]

The *Baker* Court declined to "attempt any definitive articulation" of such political "defects," but it did establish two categories. A state might

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196. *Id.* at 565 n.8 (Powell, J., dissenting).

197. North Carolina did not ratify the Constitution until November 21, 1789 – after the Bill of Rights had been approved by Congress and forwarded to the States on September 25, 1789. Rhode Island did not ratify the Constitution until May 29, 1790.

198. *Garcia*, 469 U.S. at 569 (Powell, J., dissenting).

199. AKHIL REED AMAR, THE BILL OF RIGHTS 123 (1998); EDWARD DUMBAULD, THE BILL OF RIGHTS AND WHAT IT MEANS TODAY 163 (1957).

200. AMAR, *supra* note 199, at 126-27 (1998) (discussing statements of, *inter alia*, George Mason, Luther Martin, Thomas Tredwell, and James Madison).

201. 485 U.S. 505, 512 (1988).

202. *Id.* (emphasis added).

allege (1) that "it was deprived of any right to participate in the national political process" or (2) that "it was singled out in a way that left it politically isolated and powerless."[203] To be sure, every effort to invoke this defective-process exception to *Garcia*—and there have been at least a dozen of them—has failed. Yet, on closer inspection, it is fair to say those efforts failed because they misconceived the specific Tenth Amendment argument left open by the Court in *Baker*. Most of these cases focused on the first category of process defect mentioned by the Court—the deprivation of a state's right to participate in the national political process—and did not even allege the second category—being singled out and politically isolated.[204] Several states have tried to invoke the first exception identified in *Baker* by arguing that they were deprived of political participation because their representatives or senators were not present during the congressional debates or committee meetings on the challenged legislation. These arguments failed because in each case all the usual legislative rules had been followed. A state has no entitlement to have its delegates appointed to a given committee of Congress, and principles of federalism are not implicated simply because a state gets out-voted, much less because a state's senators or representatives fail to show up and participate in a given committee meeting or floor debate.[205]

Baker's second category, however, may comfortably apply to the predicament in which Nevada finds herself after passage of the Joint Resolution. Although the *Baker* Court did not explicitly elaborate on what it had in mind when it spoke of the political isolation of a state (in large measure because South Carolina did not invoke it), in both *Baker* and *Garcia* the Court gave us a great deal of information to help determine the contours of this category.

In touting the adequacy of the political process to protect states' rights, *Garcia* relied first and foremost on the theories of James Madison, who "explained that the Federal Government 'will partake sufficiently of

203. *Id.* at 512-13.

204. Printz v. United States, 521 U.S. 898 (1997); Adams v. Dep't of Juvenile Justice, 143 F.3d 61, 65 (2d Cir. 1998); Reich v. New York, 3 F.3d 581, 589 (2d Cir. 1993); Nevada v. Skinner, 884 F.2d 445, 452-54 (9th Cir. 1989); Int'l Ass'n of Firefighters v. West Adams County Fire Prot. Dist., 877 F.2d 814, 821 & n.9 (10th Cir. 1989). *See* New Jersey v. United States, 91 F.3d 463, 469 (3d Cir. 1996); Mack v. United States, 66 F.3d 1025, 1033 n.10 (9th Cir. 1995), *rev'd on other grounds sub nom.*; Schmitt v. Kansas, 844 F. Supp. 1449, 1455 (D. Kan. 1994); Delaware v. Cavazos, 723 F. Supp. 234, 245 (D. Del. 1989), *aff'd*, 919 F.2d 137 (3d Cir. 1990).

205. *See* EEOC v. Vermont, 904 F.2d 794, 802 (2d Cir. 1990); Nevada v. Watkins, 914 F.2d 1545, 1556-57 (9th Cir. 1990), *cert. denied*, 499 U.S. 906 (1991); Nevada v. Burford, 708 F. Supp. 289, 300-01 (D. Nev. 1989), *aff'd*, 918 F.2d 854 (9th Cir. 1990), *cert. denied*, 500 U.S. 932 (1991).

the spirit [of the States], to be disinclined to invade the rights of the individual States, or the prerogatives of their governments.'"[206] But the rest of that *Federalist* paper reveals that Madison's analysis was expressly predicated on the premise that the national legislature had to act by generally applicable laws, rather than by laws applicable to, and burdening, only one named, isolated state:

> But ambitious encroachments of the Federal Government, on the authority of the State governments, would not excite the opposition of a single State or of a few States only. They would be signals of general alarm. Every Government would espouse the common cause. A correspondence would be opened. Plans of resistance would be concerted. One spirit would animate and conduct the whole.[207]

Only if "an unwarrantable measure of the Federal Government" applied and was unpopular in multiple "states" would "the means of opposition to it" be "powerful and at hand."[208] Madison explained that federal measures encroaching on state governments would be defeated politically because they "would be contending against thirteen sets of representatives, with the whole body of their common constituents on the side of the latter."[209]

With this foundation in *Garcia, Baker* elegantly conveys a great deal by citing Justice Stone's famous footnote four from *United States v. Carolene Products Co.*[210] The Carolene Products Company had challenged the constitutionality of a federal statute that prohibited the shipment of compounds of milk and other fats in interstate commerce. This was an obscure subject matter, to be sure, but the equal protection claim advanced by Carolene Products generated, in footnote four, a statement from the Court of perhaps the single most important element of equal protection doctrine. Specifically, a statute directed at "discrete and insular minorities" tends to limit "the operation of those political processes ordinarily to be relied upon" to ensure the equal protection of the laws.[211] When a law is written so as to apply to and burden only members of some political minority, whether defined by religious, ethnic, or other classification, the majoritarian political process is, by its very nature, unreliable at fending off such legislative oppression, for the simple

206. Garcia v. San Antonio Metro. Transit Auth., 469 U.S. at 551 (1985) (quoting THE FEDERALIST No. 46, at 319 (James Madison) (Jacob E. Cooke ed., 1961)).

207. THE FEDERALIST No. 46, at 320 (James Madison) (Jacob E. Cooke ed., 1961).

208. *Id.* at 319.

209. *Id.* at 320.

210. 304 U.S. 144, 152 n.4 (1938); *see South Carolina v. Baker*, 485 U.S. 505, 513 (1988).

211. *Carolene Products Co.*, 304 U.S. at 152 n.4.

reason that the majority is often quite happy to enact a law vexing a minority so long as that law does not apply to the majority. Hence the virtue of laws of general application and the Constitution's condemnation of bills of attainder. As Hamilton explained, a legislator is induced to enact just laws by "the necessity of being bound himself and his posterity by the laws to which he gives his assent."[212]

We thus see emerging from *Garcia* and *Baker* a rule that makes the national political process the primary bulwark of states' rights *only if* the national legislature enacts laws of general application that treat the states equally. This understanding of the "politically isolated" exception is further confirmed by examination of the antecedents on which *Carolene Products* relied. The *Carolene Products* footnote was, of course, discussing racial or religious minorities and dealing with individual rights to equal treatment under the law, but the authority it cited was *McCulloch* v. *Maryland*[213] and *South Carolina* v. *Barnwell Brothers*.[214] Since neither *McCulloch* nor *Barnwell Brothers* involved discrimination against religious or racial minorities, the *Carolene Products* Court clearly understood that the legal principle it was bringing to bear in footnote four was more fundamental and far larger than only the interests of those minorities.

McCulloch involved a tax imposed by Maryland on a federal instrumentality. Chief Justice Marshall reasoned that the "only security against the abuse of this power, is found in the structure of the government itself. In imposing a tax the legislature acts upon its constituents. This is in general a sufficient security against erroneous and oppressive taxation."[215] But this political safeguard broke down because the burden of Maryland's tax fell ultimately on all the states of the Union and thereby on their citizens, while only Maryland's citizens were represented in the Maryland legislature.[216]

Barnwell involved a state regulation banning trucks over a certain size from the state's highways. The political process did not self-correct because the burden of the regulation fell mostly on trucking companies from outside of the state. The Court reasoned that the political process is an unreliable safeguard for rights when the challenged law's "burden falls principally upon those" who are not represented in the legislature that enacted the law, or when the law does not "affect[] adversely some interests" who have political power within the state and who supported

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212. THE FEDERALIST No. 35, at 221 (Alexander Hamilton) (Jacob E. Cooke ed., 1961).
213. 17 U.S. 316, 428 (1819).
214. 303 U.S. 177, 184 n.2 (1938).
215. *McCulloch*, 17 U.S. at 428.
216. *Id.*

the law.[217]

South Carolina v. Baker itself helps to illuminate the problem of political breakdown by showing the contrasting situation. *Baker*, like *McCulloch*, was a case involving intergovernmental tax immunity, only this time it was a federal tax on a state. The Court noted that state immunity from federal taxation "arises from the constitutional structure and a concern for protecting state sovereignty."[218] As in *McCulloch*, the Court explained that the principal safeguard against abuse of this taxing power is the political process: the states, which all send delegations to Congress, will not oppressively tax themselves.[219] But as we have seen, that mechanism works only if the tax law in question does not weaken the political restraints by discriminating against a particular state. Thus, in *Baker*, the Supreme Court hinted that the federal tax *would be unconstitutional* if "Congress . . . imposed a tax that applied exclusively to South Carolina."[220] The tax at issue in *Baker* did not discriminate against South Carolina, nor even against States as distinguished from other taxpayers. Therefore, there was no need for federal judicial intervention.

But the vice that was absent in *Baker* is present in the context of the siting of the nation's nuclear waste dump in Nevada through the enactment of the Joint Resolution. The Joint Resolution applies by name to Nevada, and it subjects Nevada, and Nevada alone, to a unique set of criteria for licensing a high-level nuclear waste repository. A state can negotiate with other states in the Union when the issue is what general standards, rules, and criteria to apply in deciding where to dump nuclear waste, because all states have an interest in fair and workable rules, given that they are all at risk of being stuck with the waste. But when rules and standards of general application have been summarily dispensed with and one site has been arbitrarily chosen, then the state where that site is located loses its natural allies in the national political process and has, indeed, been "singled out in a way that le[aves] it politically isolated and powerless."[221]

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217. *Barnwell Bros.*, 303 U.S. at 184 n.2.

218. *South Carolina v. Baker*, 485 U.S. 505, 518 n.11 (1988).

219. *Id.* at 512-13; Helvering v. Gerhardt, 304 U.S. 405, 416 (1938).

220. *Baker*, 485 U.S. at 516; *see id.* at 525-26 n.15 ("The nondiscrimination principle at the heart of modern intergovernmental tax immunity case law does not leave States unprotected from excessive federal taxation—it merely recognizes that the best safeguard against excessive taxation (and the most judicially manageable) is the requirement that the government tax in a nondiscriminatory fashion.").

221. *Id.* at 513.

F. The Property Clause: Carte Blanche to the National Government?

As we unveil the edifice of protections for state sovereignty fashioned by our Constitution's federalist structure, it is important not to lose sight of the counterbalancing protections for the national government's sovereign choices in that same structure. Foremost among those protections that are relevant here is the Property Clause.

Yucca Mountain is federal property. Indeed, it has allegedly been owned by the federal government since Nevada was a mere territory. The Property Clause provides that "Congress shall have Power to dispose of and make all needful Rules and Regulations respecting the Territory or other Property belonging to the United States."[222] Yet, congressional power to "make all needful Rules and Regulations respecting" federal property within a state does not strip the state of concurrent jurisdiction. It merely gives Congress a measure of jurisdiction over the same lands—jurisdiction that, pursuant to the Supremacy Clause, trumps any conflicting state regulation:

> [W]hile Congress can acquire exclusive or partial jurisdiction over lands within a State by the State's consent or cession, the presence or absence of such jurisdiction has nothing to do with Congress' powers under the Property Clause. Absent consent or cession a State undoubtedly retains jurisdiction over federal lands within its territory, but Congress equally surely retains the power to enact legislation respecting those lands pursuant to the Property Clause. And when Congress so acts, the federal legislation necessarily overrides conflicting state laws under the Supremacy Clause.[223]

Nevada remains free to regulate Yucca Mountain (for example, by the state's criminal statutes or laws of trespass), but only insofar as the

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222. U.S. CONST. art. IV, § 3, cl. 2.

223. Kleppe v. New Mexico, 426 U.S. 529, 542-43 (1976)(citations omitted). *See also* James v. Dravo Contracting Co., 302 U.S. 134, 141-42 (1937) ("[I]t is not unusual for the United States to own within a State lands which are set apart and used for public purposes. Such ownership and use without more do not withdraw the lands from the jurisdiction of the State. The lands 'remain part of her territory and within the operation of her laws, save that the latter cannot affect the title of the United States or embarrass it in using the lands or interfere with its right of disposal.'") (quoting Surplus Trading Co. v. Cook, 281 U.S. 647, 652 (1930); Utah Power & Light Co. v. United States, 243 U.S. 389, 404 (1917) ("True, for many purposes a State has civil and criminal jurisdiction over lands within its limits belonging to the United States, but this jurisdiction does not extend to any matter that is not consistent with full power in the United States to protect its lands, to control their use and to prescribe in what manner others may acquire rights in them."); Nevada v. Watkins, 914 F.2d 1545, 1554 (9th Cir. 1990).

regulations do not conflict with the federal government's chosen use for the property—namely, as a nuclear waste dump. The Property Clause confers on Congress something like a police power over federal property.[224] Indeed, the Property Clause comes complete with its own textual analog of the Necessary and Proper Clause,[225] insofar as Congress is empowered to "make all needful Rules and Regulations respecting the Territory or other Property belonging to the United States."[226] Thus, the clause, "in broad terms, gives Congress the power to determine what are 'needful' rules 'respecting' the public lands,"[227] and "while courts must eventually pass upon them, determinations under the Property Clause are entrusted primarily to the judgment of Congress."[228]

That being said, nothing about this deference to congressional policy judgments places the Property Clause power beyond other constitutional curbs on government power. While *Kleppe v. New Mexico* recognized that "Congress exercises the powers both of a proprietor and of a legislature over the public domain,"[229] in our constitutional regime neither proprietors nor legislatures have absolute power (even regarding subjects appropriately within their purview). Moreover, *Kleppe* does not suggest that the Property Clause conveyed such absolute power to Congress.[230] Exercises of the power delegated by the Property Clause, just like exercises of the commerce power, must still be compatible with the principles of federalism embodied in the Constitution. As *Ashwander v. Tennessee Valley Authority*,[231] explains: "The [Property Clause] is silent

224. *See* Camfield v. United States, 167 U.S. 518, 525 (1897) ("The general Government doubtless has a power over its own property analogous to the police power of the several States, and the extent to which it may go in the exercise of such power is measured by the exigencies of the particular case."); *Utah Power & Light*, 243 U.S. 389, 405 ("And so we are of opinion that the inclusion within a State of lands of the United States does not take from Congress the power to control their occupancy and use, to protect them from trespass and injury and to prescribe the conditions upon which others may obtain rights in them, even though this may involve the exercise in some measure of what commonly is known as the police power."); *Kleppe*, 426 U.S. at 540 ("Congress exercises the powers both of a proprietor and of a legislature over the public domain."); United States v. San Francisco, 310 U.S. 16, 29 (1940) ("[T]he power over the public land thus entrusted to Congress is without limitations"); California Coastal Comm'n v. Granite Rock Co., 480 U.S. 572, 580 (1987) (same); *Watkins*, 914 F.2d at 1553 ("Yucca Mountain is federally owned land, subject to Congress' plenary power to regulate its use.").

225. *See* U.S. CONST. art. I, § 8, cl. 18.

226. U.S. CONST. art. IV, § 3, cl. 2.

227. *Kleppe*, 426 U.S. at 539.

228. *Id.* at 536.

229. *Id.* at 540.

230. *Id.* at 537-38.

231. 297 U.S. 288, 338 (1936). *See also Watkins*, 914 F.2d at 1553-54 ("The powers granted to Congress to legislate in specific areas 'are always subject to the limitation that they may not be exercised in a way that violates other specific provisions of the Constitution.'") (quoting Williams v. Rhodes, 393 U.S. 23, 29 (1968)).

as to the method of disposing of property belonging to the United States. That method, of course, . . . must be consistent with the foundation principles of our dual system of government and must not be contrived to govern the concerns reserved to the States."[232]

Indeed, *Kleppe's* link of Property Clause power to the Supremacy Clause confirms the existence of such constitutional limits. "The Supremacy Clause . . . makes 'Law of the Land' only 'Laws of the United States which shall be made in Pursuance [of the Constitution];' so the Supremacy Clause merely brings us back to the question" whether the challenged laws "violate state sovereignty and are thus not in accord with the Constitution."[233] Thus, the Property Clause, though it undeniably gives the national government broad discretion over federal land, does not give the national government a pass on other constitutional constraints on its power.

III. FORMULATING AN ARGUMENT

In light of this dynamic of federalism permeating the constitutional structure of our government, certain basic principles are evident from which Nevada built its constitutional arguments:

- Federalism analysis draws on the entire Constitution.
- Protection of state sovereignty lies at the core of our federal structure.
- The Constitution mandates equal treatment for the sovereign states.
- Congress may not single out a state for adverse treatment, but must legislate by generally applicable, neutral criteria.

The original NWPA repository standard put all fifty states in the same situation: they were *all* potential candidates to host the nation's radioactive waste. A *single* set of *neutral*, scientifically based standards was developed to govern evaluation and certification of nuclear waste

232. 297 U.S. 288, 338 (1936). *See also Watkins*, 914 F.2d at 1553-54 ("The powers granted to Congress to legislate in specific areas 'are always subject to the limitation that they may not be exercised in a way that violates other specific provisions of the Constitution.'") (quoting Williams v. Rhodes, 393 U.S. 23, 29 (1968)).

233. *Printz*, 521 U.S. at 924-25 (quoting U.S. CONST. art. VI, cl. 2). *See also* Alden v. Maine, 527 U.S. 706, 731 (1999); Fed. Mar. Comm'n v. South Carolina State Ports Auth., 535 U.S. 743, 766-68 (2002).

repositories *everywhere* in the United States. The core of those standards was deep geologic isolation. Under this regime, some states were more at risk of getting the repository due to variations in local geology, hydrology, and other variables relevant to the NWPA's standards. But any resulting differential impact among the states of these "facially neutral" criteria was attributable to the "accident of geo[logy], not any deliberate discrimination against" any state.

All this vanished when DOE discovered that Yucca Mountain was not suitable under NWPA standards. Yucca geology could contribute virtually nothing to the repository system's waste isolation capabilities. DOE reacted to this discovery by simply rewriting the rules. These new standards for engineered containment of waste apply *exclusively* to Nevada's Yucca Mountain. The Joint Resolution's approval of a repository applies, by name, only to "Yucca Mountain, Nevada." This maneuver grossly discriminates against Nevada. The rules requiring deep, permanent geologic isolation remain in effect to govern the development of any repository that might be proposed in any other state. But in Nevada, a repository can now be built, despite the failure to meet that standard, by virtually exclusive reliance on man-made containers. Thus, forty-nine states get "permanent deep geologic disposal" while Nevada gets metal drums and wishful thinking.

It would be hard to invent a clearer example of a *Baker* defect in the political process. A state can negotiate and politick with other states when the issue before Congress is what general standards to apply in deciding where to bury nuclear waste because all states have an interest in fair, reasonable, and workable rules given that they are all at risk of being stuck with an unpopular burden. But when rules of general application have been abandoned, and the question is simply a yea or nay on whether to put waste in one designated site arbitrarily chosen and announced in advance, then the state where that site is located loses its natural allies in the national political process and has, indeed, been "singled out in a way that le[aves] it politically isolated and powerless."[234]

Perhaps the sovereign state of Nevada would have to accept the nuclear waste repository if, after application of reasonable, agreed-upon, generally applicable criteria, it turned out that Nevada was the best place for the nation to put it—just as Virginia and Maryland in the eighteenth and nineteenth centuries had to tolerate, in the national interest, the erection of coastal forts necessary to protect the approaches to the Chesa-

234. The truncated legislative procedures specially enacted for the joint resolution even foreclose the use of those mechanisms that a minority can normally employ to have its concerns addressed in congressional deliberations: extended consideration in committee, filibuster, and amendments.

peake Bay and the nation's capital. But Nevada should not have to tolerate an imposition that resembles not so much national legislation as a group mugging. Thus, here the failure of the usual political check on violations of state sovereignty is linked to the nature of the violation of state sovereignty itself.

Nevada's argument does not generate a constitutional claim whenever legislation affects only one state: that happens routinely, *e.g.*, when Congress passes legislation respecting a particular national park within the borders of one state, or respecting oil leases off a particular state's coast, or respecting some other unique problem affecting only one state. But such legislation operates in accord with general standards and criteria apart from the fact that the legislation's impact will happen to focus within a particular state: *i.e.*, a given national park has special needs, or Alaskan oil drilling in the tundra presents special problems, *etc.* The case is different when legislation singles out one state, by name, to bear a unique burden on behalf of all of the states, not because that state is best situated to bear that burden, in accord with some set of generally applicable criteria, but only because the rest of the states, acting through the national government, have cynically concluded "better him than me" and have arbitrarily imposed the invasive burden on that lone state as a unapologetic act of naked political will.

The geology of Yucca Mountain will contribute virtually *nothing* to containing radioactivity; virtually *everything* now depends on man-made barriers. A waste containment system built entirely on engineered barriers can be put literally anywhere. Therefore, there is no longer any basis for preferring Nevada to New York, California, or Virginia. Indeed, Yucca Mountain is only ninety miles from Las Vegas, the fastest- growing city in the United States.

This argument does not make light of the problem posed by the long-term, safe disposal of radioactive waste. However, it is precisely in such circumstances, when the urgency of addressing such a public problem seems most acute, that the wisdom of our Constitution must inject a certain humility and restraint into public policy. As the Supreme Court put it, "The shortage of disposal sites for radioactive waste is a pressing national problem, but a judiciary that licensed extraconstitutional government with each issue of comparable gravity would, in the long run, be far worse."[235]

235. *New York v. United States*, 505 U.S. at 187-88.

A. The Argument Is Tested: The D.C. Circuit Proceedings

On January 14, 2004, a panel of the D.C. Circuit heard oral argument on the thirteen consolidated cases involving the Yucca Mountain facility.[236] Nevada's constitutional case against the Joint Resolution was among them. The court's questions concerning the constitutional argument evidenced considerable skepticism on the part of the panel, essentially focusing on the scope of the national government's prerogatives over federal land under the Property Clause. The sticking point for the panel was what one judge called Nevada's creating "this equality argument out of the standard rational basis test."[237] The thrust of the panel's objection was not that the national government had unlimited discretion under the Property Clause, but simply that

> [i]t's their property, and so if they're required to show that it's a rational regulation, it seems to me the more reasonable argument is they have to show that it's rational as to this piece of property, not as to all other pieces of property, not as to all other pieces of property that they could have regulated similarly, and they chose only to regulate this one.[238]

Elaborating on this point, two questions posed by Judge Tatel illuminated the key issue:

> Where do you draw the line between, as you said, nuclear waste depository sites and major prisons and all other uses of federal property?
>
> . . .
>
> So your principle, then, really is that Congress cannot rationally use its own property in a particular state without making sure that that particular use is neutrally, based on neutral principles, justifiable in terms of all other property?[239]

Unfortunately, these exchanges with the panel suggested that the panel misconceived the thrust of the argument. The respect that must be accorded to the sovereignty of a state does not create some rigid requirement that the national government must undertake a comparative

236. The panel consisted of Judges Edwards, Tatel, and Henderson.

237. Transcript of Oral Argument, Nuclear Energy Inst. v. United States Environmental Protection Agency, No. 01-1258, *et al.*, at 120 (Jan. 14, 2004) (Judge Tatel).

238. *Id.* at 122 (Judge Edwards).

239. *Id.* at 164 (Judge Tatel).

analysis among all federal property in every other state whenever it wants to do something on its property in one state. What the sovereignty of a state entails depends on the particular circumstances.

This can be understood by examining Judge Tatel's hypothetical, the siting of a prison versus the siting of a nuclear waste repository. At first blush, there seems to be a nice symmetry here: a penitentiary imprisons dangerous criminals while the repository imprisons toxic waste. But that is not true. With wholesale abandonment of geologic isolation (and the inevitable failure of the man-made containers holding the waste), the long-term disposal of waste at the repository at Yucca Mountain now relies, not on imprisoning the waste, but on its slow dilution through the surrounding Nevada countryside as it *by design* seeps out of the repository itself.[240]

In other words, the Yucca Mountain nuclear waste repository is now designed to rely on the territory outside the repository to do its job. That is the burden that Nevada is being forced to bear with the Yucca Mountain facility, a highly dangerous burden that surely implicates the state's sovereign responsibility for the health, safety, and welfare of its residents. How the national government uses its property, when that use is a high-level nuclear waste septic field crossing into state territory and sited above state water, inherently implicates the sovereign concerns of a state. Why a particular state should bear this risk on behalf of the whole nation, as opposed to other sites in other states, *is* inherently part of any rational basis for *this particular use* of federal property. That is, Judge Tatel was quite right in sensing that there is not a stark line to be drawn between Nevada's argument, sounding in equal protection notions, and rational basis concerns.

In short, there are really two steps in the proper analysis here. First, is the site, in the words of Judge Tatel, "geographically suitable"?[241] Second, if the site does belong in the group of sites that are geographically suitable, why choose this site as opposed to other suitable sites?[242]

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240. As EPA acknowledged, "during the post-closure period, the ground water will transport radionuclides released from the repository to the surrounding area." EPA, *Radiological Pathways Through the Biosphere*, in Background Information Document for 40 C.F.R. 197, at 8-1 (June 2001).

241. Judge Tatel suggested that the rational basis for a lawful use of federal land need only be a determination that "Yucca Mountain was geographically suitable." Transcript of Oral Argument at 162, *Nuclear Energy Inst* (No. 01-1258). Even if that were sufficient, the determination rests on a question of fact, not of policy. The question, then, would be whether it is true as a factual, scientific matter that the Yucca geography is "suitable." Surely Congress's say-so in the joint resolution cannot definitively resolve the question.

242. To be sure, the rational basis for selecting an otherwise suitable site from among others could rest on a variety of concerns, including the comparative cost of constructing a facility there, the relative accessibility of the site to reliable avenues of transportation, and so on.

Correspondingly, we normally do not think of the security of a prison as being achieved by letting the inmates run through the countryside. The risk of an escape from a federal prison is relatively remote, and in any event a hypothetical escapee would be trying to get as far away from that site as possible. Thus, it is fair to say that the siting of a prison on federal property does not, without more, implicate the state's sovereign responsibility for the health, safety, and welfare of its residents to a degree anywhere near the level of a nuclear waste dump. As a result, the sovereign concerns of the state could be fully respected if the siting of the prison were otherwise rational, that is, if the obvious concerns for the security of nearby residents were fully addressed by the location, design, and operation of the prison.[243]

B. The Case Decided?

The D.C. Circuit handed down its decision in the Yucca Mountain cases on July 9, 2004. As was expected from the tenor of the Court's questions during oral argument, it ruled against Nevada's constitutional argument. The decision was disappointing not simply because Nevada lost, but because the Court's reasoning was surprisingly superficial, utterly failing to come to grips with the substance of the arguments Nevada had offered.

To the D.C. Circuit panel, "the plenary nature of Congress's Property Clause authority [and] the considerable deference that we accord to Congress's judgment in exercising that authority" determined the outcome.[244] Given the broad scope of the Property Clause power as the Court understood it, the Court's only role was limited to "determining whether there is a rational relationship between Congress's stated end and its chosen means."[245] Here, the Court summarily concluded that the "Administration had adequately demonstrated that the Yucca site was likely to be suitable for development" as the much-needed national radioactive waste dump.[246] The Court could not go farther "to examine the strength of the evidence upon which Congress based its judg-

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243. Yet in a particular case the facts could be different enough to require more even in the siting of a prison. If, for example, the federal government decided to put all its most dangerous, clever inmates, all convicted of horrible crimes, in one new super-secure facility, it may be that a location in one State makes much more sense than a location in another in terms of minimizing the risks to the surrounding population, and that such a comparative analysis of different sites would be required to respect the sovereign concerns of the involved States for the safety of their residents.

244. *NEI*, 373 F.3d at 1308.

245. *Id.* at 1304.

246. *Id.*

ment."[247] Consequently, the Joint Resolution was an appropriate exercise of Congress's authority under the Property Clause.

The D.C. Circuit did acknowledge that it was required to go somewhat farther to examine "whether the Resolution violates some other provision of the Constitution."[248] In launching that examination, the Court recapitulated what it called Nevada's "equal treatment" claim, and even noted that Nevada's argument "is not based upon any specific provision of the Constitution, but rather on principles of federalism ostensibly inherent in the Constitution as a whole."[249] Notwithstanding this apparent recognition of the premises of Nevada's constitutional case, the Court then proceeded to analyze the state's argument in terms confined to the specific facts and circumstances of each case that Nevada had offered as a manifestation of the "dual sovereignty" that shapes and informs the Constitution.[250] With that method, it was easy for the panel to conclude that Nevada's argument "has no textual basis in the Constitution."[251]

This opinion is flawed on many levels. Most alarmingly, it is at war with the proposition that principles of federalism *are* inherent in the Constitution, and the opinion treats the Property Clause as an unbounded reservoir of federal power.

The Court's Property Clause analysis most obviously ignores the Supreme Court's admonition that exercises of Property Clause power "must be consistent with the foundation principles of our dual system of government and must not be contrived to govern the concerns reserved to the States."[252] Nowhere in the opinion is there the slightest recognition that Nevada may have some appropriate concern about the impact of a highly radioactive waste dump on its citizens and its environment, especially since, as the Court itself acknowledged, radiation even at lower doses "can have devastating health effects, including increased cancer risks and serious birth defects such as mental retardation, eye malformations, and small brain or head size."[253] To be sure, the Court acknowledged that the whole point of a genuine "geologic" nuclear waste repository was "to isolate this waste for . . . epochal years."[254] That is, "the disposal system's 'natural barriers,' *i.e.*, the characteristics of the rock formations under Yucca Mountain, are intended to protect the waste

247. *Id.*
248. *Id.* at 1305.
249. *Id.*
250. *See id.* at 1304-09.
251. *Id.* at 1308.
252. Ashwander v. Tenn. Valley Auth., 297 U.S. at 338.
253. *NEI*, 373 F.3d at 1258.
254. *Id.* at 1261.

from water infiltration and to dilute radiation releases expected to occur from leakage of the engineered barriers or from their failure thousands of years from now."[255] The suitability of the Yucca Mountain site for a radioactive waste dump accordingly rests on this foundation: the "Energy Department expects that this surrounding rock will both limit water from seeping into the waste packages and delay radioactive particles from migrating into the human environment."[256]

Put in the most practical terms, Nevada's fundamental complaint against the Yucca Mountain facility is that its "rock formations" will not do what DOE "expects" they will do; they will not provide sufficient isolation of the radioactive waste to be dumped there to protect the health and environment of Nevadans. Nevada's status as a sovereign state surely gives it a legitimate responsibility to protect the health and environment of its citizens from such danger, a responsibility that the structure of dual sovereignty established by the Constitution respects and accommodates far more than the D.C. Circuit's decision would allow.

The utter lack of respect for state sovereignty in the D.C. Circuit's opinion is evident from the fact that these judges did not find their notion of a near-absolute federal power in the Property Clause in any way jarring to their constitutional sensibilities. To this panel, such a power is "merely the natural and constitutionally unobjectionable result of the Supremacy Clause."[257] Yet this breezy observation is merely an exercise in circular reasoning. As discussed above, a federal law not made "in pursuance" of the Constitution – that is, a law that violates state sovereignty – does not become the "law of the land" under the Supremacy Clause.[258] The D.C. Circuit did not even consider the implications of Nevada's status as a sovereign state—and the legitimate public interests it has a duty to vindicate—in its application of the Property Clause to Nevada's case. Thus, while a simple reference to the Supremacy Clause may mark the beginning of the constitutional analysis needed to adjudicate Nevada's claim, it certainly does not—indeed, cannot—mark its conclusion.

The failure of the panel to address the bounds state sovereignty may place on the Supremacy Clause lies at the heart of their flawed reliance on *Kleppe* to reach their result. As the last major pronouncement of the Supreme Court on the Property Clause, *Kleppe* was bound to loom large in this case. But in fairness to the *Kleppe* Court—and to fairly appreciate what *Kleppe* may or may not mean—it must be remembered that the *Kleppe* plaintiffs claimed that Congress had no power whatsoever to pro-

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255. *Id.*
256. *Id.*
257. *Id.* at 1306.
258. *See supra* note 233.

tect wild horses on federal lands unless those horses were moving in interstate commerce or were damaging federal land.[259] It was in rejecting these severe qualifications on the scope of the Property Clause power that *Kleppe* held that this federal power is "without limitations,"[260] and "necessarily overrides conflicting state laws."[261] *Kleppe* involved no claim that some other constitutional principle constrained how the government protected these horses; its focus was solely on whether the government had the power to enact such protections at all.[262]

While deferring to Congress in making "needful" rules for federal property, *Kleppe* does not suggest that such rules are beyond judicial scrutiny, but that the "courts must eventually pass on them."[263] The D.C. Circuit correctly noted that the courts are not to "reweigh the evidence" animating Congress's action.[264] Yet that proposition cannot justify the panel's rejection of Nevada's far more fundamental constitutional claim, which sought no such "reweighing" of closely competing evidence. Rather, Nevada claimed that Congress had *no* basis by which to choose Yucca Mountain, from among all other possible locations, for the nation's radioactive waste repository. Most strikingly, there is not even a rational basis to conclude that the Yucca Mountain site is suitable for such a repository, irrespective of whether it is a rational location from among all the other possible sites.

Of course, although the D.C. Circuit was willing to broadly defer to the judgment of Congress in siting a nuclear waste dump at Yucca Mountain, the panel did conclude that there "is a rational relationship between Congress's stated purpose . . . and its decision to approve the Yucca site."[265] Yet it is impossible to see how the panel's fairly cursory conclusion that the Joint Resolution had a rational basis could be correct, given the panel's decisions with respect to other issues in the Yucca Mountain cases.

The D.C. Circuit rested its "rational basis" conclusion on the fact that a "primary purpose" of the NWPA was that a nuclear waste repository "'provide a reasonable assurance that the public and the environment will be protected from the hazards posed by' such wastes."[266] The

259. 426 U.S. at 532-33.

260. *Id.* at 539.

261. *Id.* at 543.

262. As the *Kleppe* Court noted, the exercise of the Property Clause power "merely overrides the New Mexico Estray Law insofar as it attempts to regulate federally protected animals." *Id.* at 545.

263. *Id.* at 536.

264. *NEI*, 373 F.3d at 1304 (quoting *Kleppe,* 426 U.S. at 541 n.10).

265. *Id.*

266. *Id.* (quoting 42 U.S.C. § 10131(b)(1)).

Court observed that the relevant Senate committee report had concluded "that the Administration had adequately demonstrated that the Yucca site was likely to be suitable for development" of such a repository.[267] Although in its Property Clause analysis the panel stopped there, earlier in this opinion it had concluded that the "Administration" had used the *incorrect* standard in concluding that the "public and the environment" would be protected from the hazards of radioactive wastes at the Yucca Mountain site.

The key issue, obviously, in determining whether a repository site will work to safely dispose of radioactive wastes is whether it will in fact "isolate" those wastes for the time needed.[268] The question then becomes what amount of time is needed for such isolation. Put another way, the question is how far into the future must we measure the amount of radioactivity inevitably leaking from a repository in order to say with reasonable confidence that that site can safely isolate radioactive wastes. For Yucca Mountain, the EPA adopted a rule that would measure the radiation leaking from the repository 10,000 years after nuclear waste was dumped there.[269]

However, in authorizing EPA to promulgate health and safety standards for the Yucca Mountain repository, Congress, in the Energy Policy Act of 1992, required that EPA's standards be "based upon and consistent with the findings and recommendations of the National Academy of Sciences."[270] As the D.C. Circuit itself emphasized, NAS "expressly rejected 10,000 years as a proper benchmark."[271] NAS rejected the 10,000-year standard quite logically on the ground that the measurement of escaping radiation should "be conducted for the time when the greatest risk occurs."[272] According to NAS, "at least some potentially important exposures might not occur until after several hundred thousand years,"[273] with "the highest critical group risk . . . calculated to occur . . . on the order of [one million] years."[274] In short, the EPA did not even come close to promulgating a safety standard "consistent with" NAS's recommendation—the standard commanded by Congress based on its judgment of what would make a safe repository site. As the D.C. Circuit

267. *Id.*

268. *See id.* at 1261.

269. *Id.* at 1262; Protection of Environment, 40 C.F.R. § 197.20 (2004).

270. *Id.* at 1267 (quoting Energy Policy Act of 1992, Pub. L. No. 102-486, 106 Stat. 2776, 2921 (1992) (codified at 42 U.S.C. § 10141(2000)).

271. *Id.* at 1271.

272. *Id.* at 1270 (quoting Committee on Technical Bases for Yucca Mountain Standards, Nat'l Research Council, *Technical Bases for Yucca Mountain Standards* 6-7 (1995) ("NAS Report")).

273. *Id.*

274. *Id.* at 1271 (quoting NAS Report at 67).

put it, the agency "unabashedly rejected NAS's findings."[275] But the law did not give EPA that option:

> It was Congress that required EPA to rely on NAS's expert scientific judgment, and given the serious risks nuclear waste disposal poses for the health and welfare of the American people, it is up to Congress—not EPA and not this court—to authorize departures from the prevailing statutory scheme.[276]

Thus, the Court vacated EPA's rule (and the parts of an NRC rule that incorporated the EPA 10,000-year standard).[277]

By finding that the safety standard set by EPA did not conform to the safety standard Congress wanted the agency to establish, the D.C. Circuit dealt a profound blow to the choice of the Yucca Mountain site. EPA's 10,000-year standard ultimately infected the entire process of selecting Yucca Mountain. In recommending to the President that Yucca Mountain become the repository site, the Secretary of DOE set out three "decision criteria" that led him to recommend the Yucca Mountain site.[278] The very first was the EPA standard the D.C. Circuit concluded was unlawful: "is Yucca Mountain a scientifically and technically suitable site for a repository, *i.e.*, a site that promises a reasonable expectation of public health and safety for disposal of spent nuclear fuel and high-level radioactive waste for the next 10,000 years?"[279] As the D.C Circuit noted, the Secretary of Energy's recommendation was the core of the "Administration's case for selecting the Yucca site" that it made to Congress,[280] specifically including the Administration's reliance on the 10,000-year standard.[281] In short, Congress's decision to approve the Yucca Mountain site, which the Court said was rationally related to Congress's purpose of providing for "the safe disposal of radioactive waste,"[282] essentially rested on a measure of that safety that the Court simultaneously declared to be unlawful. The panel's conclusion that the choice of the Yucca Mountain site had a rational basis simply cannot stand in the face of its rejection of the EPA health and safety standard on which that choice was based.

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275. *Id.* at 1270.
276. *Id.* at 1273.
277. *Id.* at 1315.
278. *See* SITE SUITABILITY RECOMMENDATION, at 8.
279. *Id.* at 8-9. *See also id.* at 10 ("The EPA and NRC adopted . . . standards so as to assure . . . that after the repository is sealed, radiation doses to those in the vicinity would be at safe levels for 10,000 years.").
280. *NEI*, 373 F.3d at 1310.
281. S. REP. NO. 107-159, at 8 (2002).
282. *NEI*, 373 F.3d at 1304.

Having concluded, wrongly, that the exercise of the Property Clause power in the Joint Resolution met minimal levels of rationality, the Court then turned to the potential constraints on that power posed by other provisions of the Constitution embodied in what it called Nevada's "equal treatment" claim.[283] The Court rejected that claim, pronouncing in sweeping terms that "[w]e find it beyond serious dispute that Nevada's proposed 'equal treatment' requirement cannot reasonably be inferred from the provisions and doctrines upon which Nevada purports to rely."[284]

Quite disappointingly, the panel did not analyze Nevada's constitutional argument in the manner in which that conclusion implies. The precedents Nevada cited were simply cases in point of the application of the federalism principles embedded in the structure of the Constitution. Rather than address Nevada's argument in terms of the constitutional first principles on which it rested, the panel focused on the specific holdings or circumstances of the cases Nevada cited to reach the grand conclusion that (surprise!) Nevada's case did fit within the four corners of those cases.[285] The panel's treatment of *South Carolina v. Baker* and the Tenth Amendment illustrates their method.

The Court equated "state interests of the kind protected by the Tenth Amendment" with the "congressional regulation of state activities" simply because such congressional activity was what was at issue in *South Carolina v. Baker*.[286] Yet the Tenth Amendment does not impose a specific rule that applies only to certain kinds of federal action. Rather, it "expressly declares the constitutional policy that Congress may not exercise power in a fashion that impairs the States' integrity or their ability to function effectively in a federal system."[287] This "constitutional policy" of respecting "our system of dual sovereignty" [288] is the whole point of the Constitution; its solicitude for balancing the interests of those dual sovereigns is not so limited as to be triggered only by certain federal activities.

So thoroughgoing is this constitutional policy that even in reviewing regulations of purely private behavior courts must ensure that the "federal balance" is not "contradict[ed]."[289] The vigilance of the courts to maintain the "federal balance" has not been limited to circumstances where there is regulation of the states as states, but has been manifested

283. *Id.* at 1305.
284. *Id.* at 1308.
285. *Id.* at 1305-09.
286. *Id.* at 1305.
287. Fry v. United States, 421 U.S. 542, 547 n.7 (1975).
288. *Printz,* 521 U.S. at 923 n.13.
289. *Lopez*, 514 U.S. at 583 (Kennedy, J., concurring).

"through judicial exposition of doctrines such as abstention, the rules for determining the primacy of state law, the doctrine of adequate and independent state grounds, the whole jurisprudence of preemption, and many of the rules governing . . . habeas jurisprudence."[290] The governing principles of federalism always inform judicial review, and so are expressed in such varied ways because "the federal balance is too essential a part of our constitutional structure and plays too vital a role in securing freedom for [the Court] to admit inability to intervene when one or other level of Government has tipped the scales too far."[291] Clearly, *South Carolina v. Baker* cannot be understood as rigidly setting out the metes and bounds of either the Tenth Amendment or the federal balance of dual sovereigns that is the hallmark of the Constitution.[292]

The failure of the D.C. Circuit to address seriously Nevada's constitutional argument is also apparent from the absence of any discussion in the opinion of critically important primary sources from the framing of the Constitution, such as *The Federalist* or the records of the ratification of the Constitution. One cannot come away from this opinion without the distinct impression that this panel was fundamentally antagonistic to the classic notions of federalism that animated the Framers. Consider the Court's admission that it could not see "how the constraints demanded by Nevada's claim would be consistent with the plenary nature of Congress's Property Clause authority,"[293] or its statement that the "substantive constraint on legislation and the judicial role implicit in Nevada's 'equal treatment' requirement are, in our view, totally at odds with the broad interpretation given to Congress's Property Clause powers."[294] To both these statements the obvious rejoinder is, "Maybe so, but perhaps you have inflated the Property Clause far beyond its proper scope. The genius of the Constitution, after all, is that each constitutional power or right is hemmed in by competing powers and rights."[295]

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290. *Id.* at 578.

291. *Id.*

292. The D.C. Circuit also tried to distinguish the defects in the "political process" discussed in *South Carolina v. Baker* from what it considered to be Nevada's "substantive" objections to the Joint Resolution. *See NEI,* 373 F.3d at 1306. Since Nevada's constitutional complaint arises from the lack of neutral criteria in selecting Nevada, from among all other possible sites, to be the home of the nation's radioactive waste dump, the panel's distinction between process and substance seems arbitrary at best.

293. *Id.* at 1308.

294. *Id.*

295. To further buttress the conclusion that Nevada's constitutional argument is beyond serious consideration, the D.C. Circuit suggests that respect for the sovereignty of a state could encumber many uses of federal property – the siting of a military installation, a prison, a dam, a conservation area, and so on. *Id.* But using neutral criteria by which to choose the location of any of these facilities is hardly as burdensome as the Court suggests. Natural features often clearly dictate the locations of a dam, a conservation area, or even a fort. Indeed, irrespective

CONCLUSION

Nevada's constitutional challenge to the Yucca Mountain repository certainly made no headway in the D.C. Circuit, but it remains to be seen whether the constitutional principles championed by Nevada truly lost any ground either. At bottom, the D.C. Circuit's dismissive treatment of Nevada's argument recognizes no sovereign interest of the states that could in any way circumscribe the scope of the federal government's Property Clause power. The Court thus advanced an understanding of the Property Clause that has no principled limit grounded in the federal structure of the Constitution, suggesting that the federal government has an unfettered choice to do what it will with federal property irrespective of any competing sovereign interest of the states. Nowhere did the Court even acknowledge the authority of the states as "sovereign entities"[296] that is the "presupposition of our constitutional structure."[297]

Although Nevada's case is in many respects unique, it exemplifies a profound tension between a broad view of federal power over federal land (with an impact far beyond the federal domain) that is drawn from the Supreme Court's Property Clause precedents, and elementary principles of federalism that are at the foundation of the Constitution's structure and have been given prominence in the Court's cases over recent years. As of this writing, whether the Court will have the opportunity to address this tension in the context of Nevada's case remains to be seen. Ironically, though the D.C. Circuit rejected Nevada's complaint when articulated in constitutional terms, the panel's opinion in many respects gave Nevada the relief it needed by its rejection of the EPA's 10,000-year standard. In rejecting that standard, the D.C. Circuit rejected a health and safety standard crafted only for the Yucca Mountain site, and commanded EPA to return to what Congress had mandated: a neutral health and safety standard, applicable to any possible repository site, recommended by the scientific community. If the EPA faithfully complies, the Yucca Mountain site may in the end be judged by the neutral, rational criteria that Nevada has claimed was its right.

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of concerns for state sovereignty, the use of such criteria is simply an attribute of responsible decision-making. If one were constructing a maximum security prison for the most hardened federal convicts, for example, Alcatraz is a more logical location than Central Park.

296. *Alden*, 527 U.S. at 758.

297. Blatchford v. Native Vill. of Noatak, 501 U.S. 775, 779 (1991). *See also* THE FEDERALIST No. 40 at 261 (James Madison) (Jacob E. Cooke ed. 1961) (States are "regarded as distinct and independent sovereigns" by "the Constitution proposed").