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High-level Waste, Low-level Logic

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At Yucca Mountain, scientists have been put into a no-win either/or box.

Four years before the United States began the commercial generation of electricity by nuclear fission, James Conant, who advised President Roosevelt on the atomic bomb, predicted that the world would eventually turn away from nuclear power because of problems with waste disposal. A few years later, in 1957, a panel of the National Academy of Sciences warned: "Unlike the disposal of any other type of waste, the hazard related to radioactive wastes is so great that no element of doubt should be allowed to exist regarding safety."

Conant and the NAS panel were prescient. The safe disposal of high-level nuclear waste from power reactors has been a decades-long scientific and political problem in the United States. In an effort to resolve it, Congress in 1982 mandated permanent geological disposal, a policy consistent with the conventional wisdom on the subject. Since the 1982 mandate, the Energy Department has considered sites in Washington, Utah, Texas, Mississippi, Louisiana, Nevada, the Great Lakes area, and the Appalachian range.

After much political tugging and pulling, Congress directed in 1987 that the list of possible sites be narrowed to one. Yucca Mountain, located on the Nuclear Test Site in Nevada, would be the only location evaluated for the repository. To date, the United States has spent more than $3 billion studying—or "characterizing"—the proposed Yucca Mountain site. If scientists eventually find it acceptable, and if it survives the legal and political battle that would follow its selection, sometime early in the next century the United States would become the first country to begin permanent geological disposal of high-level radioactive waste and spent fuel from nuclear reactors.

Leaky canisters

Unhappily for the Energy Department, which oversees the site evaluation, the road to Yucca Mountain has been rocky and pot-holed. Roughly 80 percent of Nevadans oppose the facility, according to a variety of opinion polls, and a host of environmentalists and anti-nuclear activists have dedicated themselves to attacking the siting plan in general and the scientific studies in particular. Officials of the State of Nevada already have tried to veto the site, and they vow to sue the Energy Department if Yucca Mountain is finally selected.

Opposition to the repository is well founded. Some 86,000 metric tons of high-level waste and spent fuel from the civilian nuclear program await disposition. Current plans for future storage of high-level nuclear waste call for deep emplacement of steel canisters in the host rock. Federal regulations require the canisters to resist corrosion for as little as 300 years. Nevertheless, the Energy Department admits that the waste will remain dangerous for longer than 10,000 years. Department experts also agree that, at best, they can merely limit the radioactivity that reaches the environment; they claim that "there is no doubt that the repository will leak over the course of the next 10,000 years."[1]

Many of the radioactive isotopes that would be stored at Yucca Mountain—such as iodine 129, neptunium 237, cesium 137, uranium 238, zirconium 93—have half-lives in the millions of years. During such long time periods of radiotoxicity, changes in climate, groundwater, precipitation, and volcanic activity could occur. A worst-case possibility: massive releases of radioactivity into the environment.

To insure even minimum standards of safety, Yucca Mountain risk assessors need to predict precise phenomena associated with future climate, weather, mineralogy, and water composition, even though climate and weather are among the most variable and rapid natural processes influencing the repository. Even the

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Energy Department admits that "the climatic changes that are possible during the next 10,000 years at Yucca Mountain may cause changes in the hydraulic gradient.... The extent of these changes is uncertain." [2] Translated: We don't know precisely how soon the water table might be contaminated.

Major variations in the climate of Nevada have occurred during the past 45,000 years, and the U.S. Geological Survey claims that future climatic changes probably will occur during the time the waste materials remain hazardous.[3] Precipitation patterns are likewise fluctuating, and assessors must be able to predict them in perpetuity. The precipitation data, however, covers only approximately the past 30 years; yet 10,000-year precipitation predictions are crucial to the safety of Yucca Mountain, because percolating water could infiltrate and transport radioactive leachate once the containers have been breached. To assume that the 30-year precipitation data are adequate for precisely predicting the risks associated with a permanent repository represents a questionable methodological value judgment.

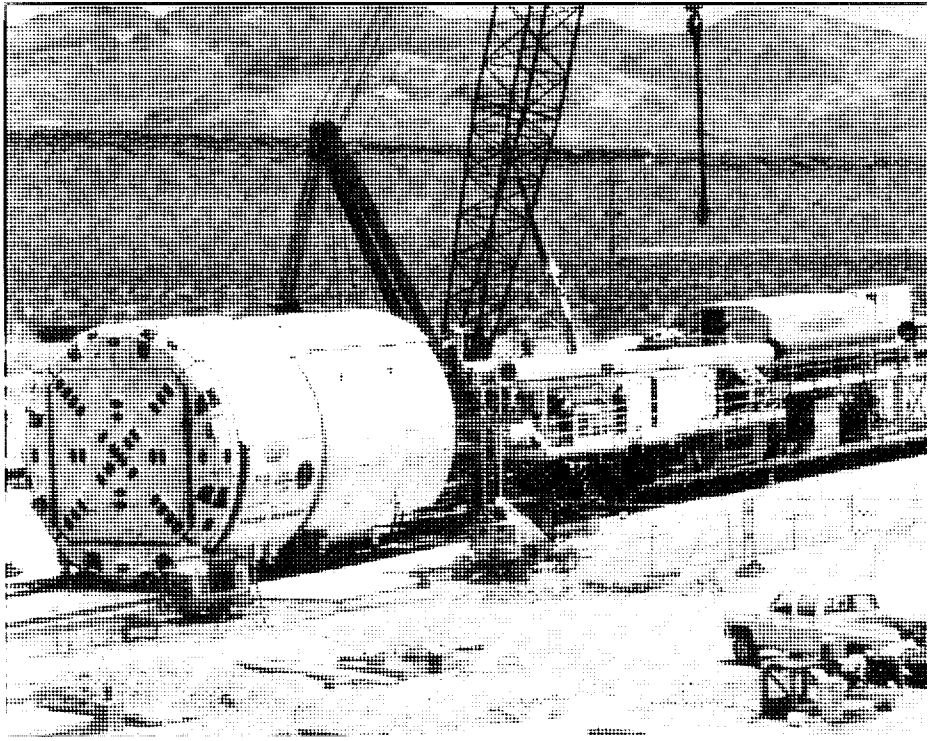
Criticism of the Yucca Mountain risk assessments generally focuses on scientific issues such as predictions regarding the flow of groundwater. While these concerns are central to characterizing the site, I also suggest that the Yucca Mountain studies exhibit at least three fundamental *logical* flaws: appeals to ignorance; appeals to authority; and the use of a two-valued, either/or "frame" for assessing site suitability.

Given these basic problems in science and logic, it makes sense for Congress to alter its course and postpone the decision about a permanent repository. Instead, the wastes should be stored for 100 years in several "negotiated, monitored retrievable storage facilities" (NMRS). A century from now, our descendants will be in a far better position to determine what to do next. "Delay," said Thomas Jefferson in another context, "is preferable to error."

Appeals to ignorance

In the everyday world, people often assume that a claim is true simply because it has not been proved false, or that a claim is false because it has not been proved true. In logic, this assumption is an invalid "appeal to ignorance"—and some of the most troubling problems in the Yucca Mountain feasibility studies arise from the repeated use of such invalid reasoning.

Appeals to ignorance occur throughout the 1992 Yucca Mountain Early Site Suitability Evaluation (ESSE) and its supporting quantitative risk assessments. For example, a group of assessors noted that a number of key factors, such as water infiltration and fracture flow, had not been considered. Nevertheless, the assessors concluded that Yucca Mountain would cause less than one "health effect" every 1,400 years.[4]



NEVADA TEST SITE—ENERGY DEPARTMENT

The "Yucca Mucker," a special boring machine for the proposed Nevada waste site.

Similarly, another team of scientists admitted that the hydraulic data at Yucca Mountain were insufficient for performing geostatistical analyses, and that they may "have underestimated cumulative releases of all nuclides during 100,000 years, by an amount that is unknown." [5] And yet, the same assessors concluded that the "repository site would be in compliance with regulatory requirements." [6]

Likewise, the 1992 ESSE admitted that the "the performance analyses did not quantitatively evaluate the potential for... disruptive processes or events such as faulting or human intrusion." Even so, the report concluded that scientists had "uncovered no information that indicates that the Yucca Mountain site is... likely to be disqualified." [7] Obviously, the analyses could not have discovered disqualifying information if the very areas that are most likely to cause problems were not investigated. (Oddly, the authors admit, a few pages later, "that disruptive processes that cause direct releases to the accessible environment provide the only conditions under which the EPA standards might not be met.")[8]

Accepting appeals to ignorance in Yucca Mountain studies virtually guarantees that, despite major uncertainties, scientists will eventually judge the site to be acceptable. In fact, the Energy Department admitted: "If... current information does not indicate that the site is unsuitable, then the consensus position was that at least a lower-level suitability finding could be supported." [9]

Geology is an explanatory, not a predictive science, says MIT geologist Kip Hodges.

To be sure, most scientists live with uncertainty. Although scientists (and risk assessors) provisionally accept hypotheses after repeated and rigorous attempts to falsify them fail, this provisional acceptance is not the same as an appeal to ignorance.

Energy Department investigators have simply ignored whole areas of investigation—such as the possibility of human error, geostatistical analyses, and worst-case scenarios. Because of their omissions, there have not been repeated and rigorous attempts to show the site to be unsuitable, as adherence to scientific methods would require. That being the case, decision-makers lack adequate grounds even for provisionally accepting the site-suitability hypothesis as offered in the ESSE.

Appeals to authority

In the absence of hard data and the experimental confirmation of many hypotheses about Yucca Mountain, assessors have often used nonquantifiable and subjective judgments to establish site suitability. The 1992 ESSE repeatedly admits that subjective judgments have played a "significant" and "critical" role in the face of inadequate data.[10]

One assessor, for example, made a number of questionable hydrological assumptions, built a computer model based on these assumptions—and then concluded that the untested model was "an effective tool for the simulation of the performance of the repository systems at Yucca Mountain."[11]

Similarly, other Yucca Mountain assessors admitted that they had ignored crucial hydrological and geological parameters; nevertheless, they concluded that radioactive releases at the site would be "significantly less" than those permitted by governmental standards.[12]

Obviously, such subjective opinions are neither inductively reasonable nor deductively valid. That fact has not gone unnoticed. The Nuclear Regulatory Commission and committees of the National Academy of Sciences have questioned the degree of certainty in the Yucca Mountain risk assessments.

Although appeals to authority are sometimes unavoidable in science, they should never misrepresent the degree of uncertainty that has been encountered. Because Energy Department assessors often do not admit their uncertainties and instead claim that the Yucca Mountain site will be suitable for 10,000 years—or even 100,000 years—they use their expertise in misleading ways.

As one Energy Department peer reviewer put it, if some data are "subjectively" determined, as the Energy Department assessors admit, then "why couldn't it [the decision that the site is "suitable"] just as well be . . . [that it is] unsuitable?"[13]

A fundamental problem with Yucca Mountain risk assessments is that U.S. government regulations require that assessors guarantee repository safety for 10,000 years. To reach that goal, the Environmental Protection Agency and the Nuclear Regulatory Commission have both spelled out specific, long-term, numerical criteria for safe disposal.

Many scientists say that precise prediction over such a timespan is impossible. Kip Hodges, a geologist at the Massachusetts Institute of Technology and a peer reviewer for the Energy Department, notes that geology is an *explanatory* science, not a *predictive* science. It is "patently absurd," he says, to attempt to predict the precise probability of volcanic disruption at Yucca Mountain for 10,000 years.[14]

Either/or

Why have assessors at Yucca Mountain used problematic appeals to ignorance and to authority? Part of the answer could be that the Energy Department has put its assessors into a box—it does not allow them to conclude that the data are inadequate or that a site decision is not yet possible. Instead, Energy forces them to employ a two-valued, black-or-white "frame" for their judgments: The site is either suitable or it is not suitable. The ESSE peer review panel put it this way:

"The DOE General Siting Guidelines . . . do not allow a 'no decision' finding . . . . Thus the ESSE Core Team followed the intent of the guidelines."[15]

That either/or constraint alarmed some members of the peer review panel. They said that there was "not enough defensible, site-specific information available to warrant acceptance or rejection of this site."[16] But there was no third alternative for the authors of the ESSE. They had to use the "site suitable/unsuitable" frame they "were given" by the Energy Department.

The warnings of the peer reviewers suggest that when rigorous and precise testing is not possible, a three-value frame (site suitable; site unsuitable; site suitability uncertain at present) would be preferable. Conventional decision theory likewise suggests that even a high probability of site suitability may not be "high enough" if the repository could pose serious consequences for public welfare. Use of an either/or frame may not be reasonable in situations where a mistake in assessment can have potentially grave public consequences.

To be sure, one does not need scientific certainty before one acts. In science, absolute certainty is unattainable. Permanent disposal of high-level waste and spent fuel at Yucca

Mountain does not require absolute certainty, but it does require more certainty than we now have.

Wait and see

The Energy Department's imposition of an either/or assessment frame may not be the only reason that Yucca Mountain studies have used problematic appeals to ignorance and authority. Policy-makers may have given the Energy Department an impossible task. According to a National Academy of Sciences committee, the U.S. approach to permanent disposal "is poorly matched to the technical task at hand. It assumes that the properties and future behavior of a geological repository can be determined and specified with a very high degree of certainty. In reality, however . . . the current program is not sufficiently flexible or exploratory."[17]

Alvin Weinberg, a nuclear power advocate for nearly 50 years, makes a related point. In 1987, he told Congress that U.S. management of high-level waste has been like a football game. We have been trying for a touchdown with permanent geological disposal. But we fumbled. Now we must try for a first down. We can do that, he said, by following the example of Sweden: Develop inherently safe nuclear waste packages "that are completely resistant, even if the repository is invaded by water, for much longer than . . . 300,000 years."[18]

Current U.S. disposal plans focus more on the repository than the waste containers. The site must be reasonably environmentally secure for 10,000 years or longer; in contrast, the waste packages need to resist leaks for only 300 years.

Weinberg's recommendation calls for an improvement in the life of the containers by three orders of magnitude. The first step in following his recommendation, he says, is to cool the wastes for up to 100 years in temporary facilities rather than for the planned 10 years. After 100 years, he estimates, the heat generated per minute by the waste would be only one-fourth as great as that produced after 10 years. Cooling also would reduce the probability of canister leaks once the waste is placed in permanent storage.

Although Weinberg favors permanent storage, he is a proponent of temporary monitored retrievable storage for the first 100 years. This wait-and-see position makes a great deal of scientific sense. Wait and see if we can develop more resistant containers. Wait and see if we can devise a way to render radioactive materials less harmful. Wait and see if we can resolve some of the uncertainties regarding long-term safety at a permanent repository.

Establishing a system of geographically scattered, retrievable storage sites is an idea that has been around for many years. For temporary storage to be successful, however, government would need to negotiate site selection with potential host communities rather than to impose facilities on them as it is now trying to do at Yucca Mountain. A negotiated system also would require the government to monitor the waste rather than simply bury it and leave it unmonitored, as planned at Yucca Mountain. Most important, it would enable the scientific and regulatory community to learn—in stages—how best to store high-level nuclear waste safely.

The overarching rationale for retrievable storage is simple. If some dangerous technologies—like those for high-level nuclear waste disposal—are unforgiving, then it makes sense to lengthen the scientific and regulatory "learning curves." Retrievability buys time and increases our scientific and ethical options.

After 100 years of experience with NMRS facilities, we would be in a better position to make decisions regarding disposal schemes. A central geological repository might still look good a century from now. But so might continued surface storage—or even sub-seabed disposal. Transmutation—showering the waste with neutrons to convert fission products to stable or short-lived radioactive isotopes—might prove workable by then, thus making it possible to think in shorter time frames for storing waste.

A future ethic

In 1972, Alvin Weinberg described the problem of nuclear wastes as a "Faustian bargain." In return for the present benefits of atomic energy, we must export the risks of its wastes to future generations. Because we have already made the bargain, we cannot avoid dealing with the radioactive wastes we have generated. We can, however, choose better or worse ways to live out the consequences of our pact with Mephistopheles.

Opposition to the proposed Yucca Mountain repository is bitter in Nevada. Part of the reason is the widespread belief among Nevadans that their state is being treated inequitably; it must bear the high-level nuclear waste burden for the entire nation. The country as a whole made the Faustian bargain, but only Nevadans are supposed to pay the price. And because the Yucca Mountain waste would not be retrievable, future generations would also pay the price. They would not have the option of freely consenting to continued storage.

Regional NMRS facilities are desirable, in part, because they would help spread the risk of disposal over time—and over the nation's

Guidelines did not allow for a "no decision" finding, only that Yucca Mountain was or was not suitable.

Negotiating with communities willing to accept temporary storage has several advantages.

geography. Neither Nevadans nor members of future generations would bear the sole burden. Multiple NMRS facilities thus would minimize the geographical and temporal inequities associated with a permanent, unmonitored, nonretrievable facility that places the greatest risks on one region and on future generations.

NMRS is not just pie in the sky. Although the Energy Department is wedded to permanent geological disposal, a number of communities have already offered to host NMRS facilities. Among them are Nye County, Nevada; Morgan County, Tennessee; and the Yakima Indian Nation, in the state of Washington. In the last issue of the *Bulletin*, Luther Carter described how the Mescalero Indians of Arizona were pitching such a plan.

The willingness of some communities to accept an NMRS suggests that temporary storage might be more politically acceptable than a permanent facility. Of course, the communities that might accept an NMRS facility are likely to be impoverished and looking for an economic boost. In Morgan County, Tennessee, for instance, the unemployment rate is far above the national average and per-capita incomes are low. Schools are poor and other services meager. About half of the local tax collected is needed merely to service the county's bonded debt. In offering to host a temporary waste facility, the representatives of Morgan County made it clear that the operators of the facility would have to underwrite a substantial portion of the county's operating expenses, including servicing its debt.

Because poverty can raise serious questions about the voluntariness of a host community's informed consent, the negotiation process would have to maximize consent, equity, and due process. Nevertheless, using NMRS facilities for a hundred years seems preferable to a central permanent repository, because it would require the imposition of fewer and shorter-term burdens on the most vulnerable groups: host communities and future generations.

Minimal fairness requires the current generation to clean up its own mess, or to somehow pay its descendants—in full—to do it.

Reading the riddle

Perhaps the most obvious objections to NMRS sites are that the facilities would be unsafe, that they would be targets for terrorist attacks, and that they would contribute to the proliferation problem.

Although the Energy Department argues that a permanent geological repository would be safer than temporary, monitored facilities, the question is, "Safer for whom?" Certainly not safer for members of future generations who might be harmed by leakage from an unmonitored facility.

Numerous members of Congress, study groups at sites wishing to host NMRS facilities, the Nuclear Regulatory Commission, and the U.S. Monitored Retrievable Storage Review Commission have affirmed the safety of 100-year storage. In 1989, after extensive study, the MRS Review Commission said simply: "MRS options are safe."

The commission supported its arguments with detailed calculations. It estimated, for example, that the total radiation doses, both to the public and to workers, would be less in the case of an NMRS facility not linked to a repository than for a permanent facility handling the same amount of waste. The review commission indicated, however, that it did not believe the safety differences were great between the two options. It likewise emphasized that the NMRS option was safer than onsite storage at reactors, in part because the NMRS facility would employ experienced fuel handlers and would have a full staff available.[19]

Admittedly, temporary storage facilities would be more susceptible to terrorism and sabotage than a permanent geological repository. But the monitoring and management of NMRS sites might make them better able to resist such attacks once they occurred. Also, given current building technology, it should be possible to construct surface structures that are extremely protective.

Another objection to deferring the decision about a permanent repository and instead using NMRS facilities for a century is that, over the long term, such storage would be more expensive than permanent disposal. A host of analysts have looked at the cost question, but it is not clear that permanent geological disposal would be cheaper. The economics of permanent disposal depends on when and how much the facility leaks. The sooner and bigger the leaks, the higher the environmental costs.

But dollar costs are not the central consideration. The main reason many people claim NMRS sites are often viewed as more expensive is that permanent geological disposal does not achieve the same level of pollution control. As just mentioned, a permanent site would leak. The scientific argument is largely over how quickly it would leak, how much it would leak, and how rapidly the leakage might reach the water table. Permanent disposal is premised on a philosophy of "dilute and disperse." In contrast, NMRS is based on containment. Dilution and dispersal of hazardous substances is always cheaper than containment.

The main problem with the economic objection to NMRS sites is that cost considerations, although an important policy determinant, ought not to be the only or the primary deter-

minant of waste policy. After all, if cost were the sole criterion for a reasonable choice, one might be able to argue for dumping radioactive materials into the sea or for using shallow land burial.

The use of narrow economic criteria for waste management is also undesirable because we have produced the radioactive materials; we have an ethical obligation to do as much as is necessary and possible to protect subsequent generations. To argue that economics ought to be the principal determinant of waste policy would be to use an expediency criterion for recognition or denial of a basic human right to equal protection of the laws.

The U.S. Constitution does not say that we have the right to life, liberty, and the pursuit of happiness "provided that it is economical to recognize the right." If U.S. nuclear waste policy is to be consistent with existing philosophical, legal, and political doctrines about human rights, then expediency ought not be our primary guide.

Yet another objection to NMRS facilities is that they might become de facto permanent repositories. We might avoid such an outcome, however, if the facilities were established with inflexible legal lifetimes. If the consequences of noncompliance were great, NMRS sites would be less likely to become permanent.

The argument that NMRS facilities might become permanent is especially weak when one considers the alternative. At the moment, government policy is to push ahead with the permanent, unmonitored, nonretrievable disposal of nuclear waste in the face of grave scientific uncertainties. With the NMRS plan, the government would admit ignorance—and then deal with it in a systematic and conservative way.

Humankind has been civilized for only about 10,000 years, yet the United States faces the task of storing radionuclides such as plutonium, which remains dangerous for more than 250,000 years. Given our short experience in handling such materials, how can we deal adequately with long-lived radioactive waste? The short answer is, "We can't." We do not yet know how to do the job right. That's why Yucca Mountain is a profoundly bad idea.

Although he did not intend it, J.R.R. Tolkien, in *The Lord of the Rings*, suggested an answer to the riddle of nuclear waste. The ring gave mastery over every living creature. But because it was created by an evil power, it inevitably corrupted anyone who attempted to use it. How should the Hobbits, who held the ring, deal with it? Erestor articulated the dilemma:

"There are but two courses, as Glorfindel already has declared: to hide the Ring forever; or to unmake it. But both are beyond our power. Who will read this riddle for us?"

Humankind will eventually read the riddle. But at the moment, in the United States and elsewhere, its complexities are beyond us. In 100 years, that may not be the case. ■

Permanent waste burial may or may not be cheaper, but cost is only one consideration.

1. Energy Department cited in R. Monastersky, "The 10,000-Year Test," *Science News* 133, no. 9 (Feb. 27, 1988), pp. 139–41. See also G. Hart, "Address to the Forum," U.S. Environmental Protection Agency, *Proceedings of a Public Forum on Environmental Protection Criteria for Radioactive Wastes*, ORP/CSD-78-2 (Washington, D.C.: U.S. Government Printing Office, May 1978), p. 6.

2. U.S. Department of Energy, *Nuclear Waste Policy Act, Environmental Assessment, Yucca Mountain Site, Nevada Research and Development Area, Nevada*, DOE/RW-0073, 3 vols. (Washington, D.C.: U.S. Department of Energy, 1986), vol. 2, p. 6-242.

3. U.S. Geological Survey, *Vegetation and Climates of the Last 45,000 Years in the Vicinity of the Nevada Test Site, South-Central Nevada* (Reston, Virginia: U.S. Geological Survey, 1985) (Item 394 in U.S. Department of Energy, DE88004834).

4. F. Thompson, F. Dove, and K. Krupka, *Preliminary Upper-Bound Consequence Analysis for a Waste Repository at Yucca Mountain, Nevada*, SAND83-7475 (Albuquerque, New Mexico: Sandia National Laboratories, 1984), pp. v–vi, 4, 47.

5. S. Sinnock and T. Lin, *Preliminary Estimates of Groundwater Travel-Time and Radionuclide Transport at the Yucca Mountain Repository Site*, SAND85-270 (Albuquerque, New Mexico: Sandia National Laboratories, 1986), p. 77.

6. Ibid., pp. i–ii.

7. J.L. Younker, W.B. Andrews, et al., *Report of Early Site-Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada*, SAIC-91/8000 (Washington, D.C.: U.S. Department of Energy, 1992), p. 2–150.

8. Ibid., p. 2–157.

9. Ibid., p. E–11.

10. Ibid., pp. 1–18, 2–6.

11. Y. Lin, *Sparton—A Simple Performance Assessment Code for the Nevada Nuclear Waste Storage Investigations Project*, SAND85-0602 (Albuquerque, New Mexico: Sandia National Laboratories, 1985), pp. i, 1.

12. Sinnock and Lin, *Preliminary Estimates*, pp. i, 47.

13. J.L. Younker, S.L. Albrecht, et al., *Report of the Peer Review Panel on the Early Site-Suitability Evaluation of the Potential Repository Site at Yucca Mountain, Nevada*, SAIC-91/8001 (Washington, D.C.: U.S. Department of Energy, 1992), p. 112.

14. Ibid., p. 384.

15. Ibid., p. B-2.

16. Ibid., pp. 460, 257, 40–51.

17. F.L. Parker et al., *Rethinking High-Level Radioactive Waste Disposal* (Washington, D.C.: National Academy Press, 1990).

18. Statement of Alvin Weinberg, Hearings Before the Committee on Energy and Natural Resources, U.S. Senate, First Session, Part 2, *Nuclear Waste Program* (Washington, D.C.: U.S. Government Printing Office, 1987), pp. 2–5; see also N. Lenssen, *Nuclear Waste* (Washington, D.C.: Worldwatch, 1991), pp. 27–28.

19. A. Radin, D. Klein, and F. Parker, Monitored Retrievable Storage Review Commission, *Nuclear Waste: Is There a Need for Federal Interim Storage?* (Washington, D.C.: U.S. Government Printing Office, 1989), pp. 30–31.