Appendixes

Appendix A-1

Radioactive Waste Management Policymaking*

Acknowledgments

In preparing this paper, the author accumulated a number of debts that he can only hope to partially repay with these words of acknowledgment. William Barnard of the Office of Technology Assessment was a constant source of encouragement and support as this effort, initially planned to be of 2 months duration, stretched into many months. He also carefully read the first draft and offered helpful criticisms. David Stewart of the U.S. Geological Survey provided much information as well as useful suggestions for improving the first draft. Alex Perge of the Department of Energy (DOE) also commented on the first version of the paper and pointed out some factual errors. Several unknown reviewers from DOE and the Nuclear Regulatory Commission (NRC) helped improve the accuracy of appendix A-2.

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Marcia Picket did an admirable job in typing the drafts and the final product.

Despite all these efforts to facilitate the work and to improve it, errors undoubtedly remain. For this I take full responsibility.

The Imperative

The philosopher Hans Jonas poses the central ethical issue of our new technological age as he observes that the days have passed when:

> **The good** and evil about which action had to care lay close to the act, either in the praxis itself ***or*** in its immediate reach, and were not a matter for remote planning . . . Proper conduct had its immediate criteria and almost immediate consummation. The long run consequences beyond were left to chance, fate or providence. Ethics, accordingly, was of the here and now, of occasions as they arise between men, of the recurrent, typical situations of private and public life. [1]

Instead, suggests Jonas,

> [T]his sphere is overshadowed by a growing realm of collective action where doer, deed, and effect are no longer the same as they were in the proximate sphere, and which by the enormity of its [technology's] powers forces upon ethics a new dimension of responsibility never dreamt of before. [2]

Advocating a new categorical imperative—' 'In your present choices, include the future wholeness of Man among the objects of your will' '—Jonas recapitulates a theme which underlay the intent of those managing radioactive waste from the time they were first produced, nearly 2 score years ago.

Introduction

Radioactive waste management is a problem that is not quite like most others that have come within the Government's purview. There are technical and institutional uncertainties associated with this problem; some of them unknown and possibly large; some of those uncertainties are, in principle, unresolvable. The cost of error may be high, and the time constant of feedback about error is great. No jurisdiction is enthusiastic about locating waste management facilities within its confines; yet if all decline, a pressing national need will not be met, thus opening the way for a repeat of the "tragedy of the commons.

This paper is about radioactive waste management problem-solving. It examines how the Federal Government responded to an issue of high complexity, potentially large risk, and intense political controversy. Eight dimensions of waste management problem-solving are considered:

- the determination of what constitutes waste;
- the storage of radioactive waste;
- the role of the earth sciences in designing waste disposal facilities;
- the development of strategies for searching for disposal sites;
- the use of engineered barriers in the design of waste disposal facilities;
- the determination of acceptable levels of risk in disposing of radioactive waste;
- the interaction between the States and the Federal Government in the area of waste management; and
- the relationship between waste management and the production of nuclear power.

For each of these elements, two questions are raised: How did a particular aspect come to be recognized as part of the "problem?" How did the understanding of

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● **The material in this appendix was prepared for OTA by Daniel Metlay of the University of Indiana under contract No. 033-2690.0, June 1981.**

[1] **Hans Jonas, "Technology and Responsibility: Reflections on the New Task of Ethics, *Social Research 40*, spring 1973, pp. 35-36,**

[2] **Ibid., p. 38.**

the eight problem elements evolve over time? Once those questions have been considered, we ask a third one: How did conceptualizations of the problem and decisions taken at one point influence problem-solving during subsequent periods of time? We shall try to learn the reasons why policymaking was sometimes quite successful and why it was sometimes not. By doing that we hope to provide insights into designing and implementing programs that might be useful guides for the future.

Before we can proceed with that analysis, the stage must be set, a foundation must be laid. For those unfamiliar with the details and history of radioactive waste management, four chronologies have been prepared and are included in appendix A-2. The chronologies describe, in turn, events dealing with waste storage, events dealing with waste disposal, events dealing with the regulation of radioactive waste, and events affecting organizational structure and responsibility for waste management. In addition, a "time line" has also been prepared and appended which shows the sequence of some of the major events in waste management history. Of more general interest, however, is a discussion of the context within which waste management problem-solving occurred. The evolution of waste management policymaking can only be partially understood without reference to that context. It is to that second component of the foundation that we now turn before addressing the eight specific areas of the problem.

The Context of the Policymaking Process

Richard Cyert and James March correctly observed that complexity and uncertainty generate dilemmas about how to act. According to them, decisionmakers in organizations appear to resolve those dilemmas through the use of a particular strategy:

> [Policymakers] make decisions by solving a series of problems; each problem is solved as it arises; the organization then waits for another problem to appear. Where decisions within the [organization] do not naturally fall into such a sequence, they are modified to do so.[3]

Thus, policymakers give pressing problems priority; what had to be done yesterday draws their first attention today. Problems which can wait, wait.

A high degree of complexity and a substantial amount of uncertainty affect policy makers' behavior in other ways as well. Decisionmakers tread carefully; they cautiously implement policies that are minimally disruptive; they monitor the consequences of their actions and evaluate whether those consequences are satisfactory or unsatisfactory. When faced with outcomes that are not acceptable, they search in the neighborhood of the existing policy to find alternatives. To simplify the complexity they confront, policymakers generally ignore factors that appear only marginally related to the core of their efforts; sometimes they even ignore factors that are substantially related but which are, for any number of reasons, intractable or elusive.

The evidence is strong that the policymaking process for the back-end of the nuclear fuel cycle followed the patterns of organizational behavior just described, at least during the three decades prior to 1975. The Atomic Energy Commission (AEC), the developer and the regulator of the nuclear power technology, deferred the search for long-term solutions to the problem of waste management. When the problem could be finessed, it was; when it could not be, waste management was dealt with in ad hoc ways. Such responses are hardly unreasonable. Indeed, given the limitations inherent in the exercise of cognitive power by individuals, as well as more mundane but important constraints such as budget ceilings, they may represent the best strategy available. Nonetheless, those responses may prove ultimately to be inadequate and insufficient; their employment may lead policymakers into situations from which they cannot easily or gracefully escape.[4]

What factors facilitated this fragmentation of nuclear power policy and the subsequent minor emphasis given to waste management? First, attitudes held by the AEC Commissioners and operating personnel played a role. The Commissioners never got personally excited about the problems of waste management. In the history of AEC, there was only one Commissioner, Clarence Larson, who took a major interest in waste management, But even he never championed the area's needs in the same manner that James Ramney pushed reactor development or Glenn Seaborg pushed physical research. For most of the Commissioners, waste was unpleasant, unglamorous, and low priority.

Evidence for this proposition comes from interviews with key participants involved in the decisionmaking processes that took place prior to 1975. One person who dealt with the Commissioners every day described the obstacles he encountered:

> To get them interested was very difficult. There was not a lot of glory in waste. No one wanted to be a champion of waste. Milt Shaw and I went to get the Kansas Governor's approval [for the Lyons repository] but not one Commissioner would go to do it. No one wanted to get tagged as having waste being his bag . . . One division or another would develop things about waste man-

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[3] Richard Cyert and James March, *A Behavioral Theory of the Firm* (Englewood Cliffs, N.J.: Prentice-Hall, 1963), p. 3.

[4] See, Daniel Metlay, *Error Correction in Bureaucracy*, unpublished Ph. D. dissertation, University of California, 1978, especially chs. 1 and 5.

> agement within the staff; the Commission tolerated it, but they were really interested in reactors . . . I'd have a hard time finding someone on the Commission who thought he was responsible for waste.[5]

A program director dealing with waste management during this period offered a similar view: "One of the problems the Commission had for years was that the emphasis was on the development of reactors and to hell with anything to feed or service reactors. That was because the sexy part of this industry was the damned reactor. A former Commissioner summed up how one of his colleagues treated the issue of waste management by recalling that "every time anyone mentioned waste to X, [he] would make a face, turn up [his] nose, and move on to another subject.

Nor could the cause of waste management be sustained through the skillful use of internal politics by personnel at lower levels. For them to pursue the issue intensely hardly made much sense. Grand careers were made in reactor development where the organization's resources were committed, not in waste disposal. Moreover, waste management also seemed to lack the intellectual challenges of reactor research or high energy physics.

A second influence, more subtle but extremely pervasive, which led policy makers to place a low priority on waste management and which reduced their sensitivity to potential errors in their actions was a sense of technological optimism. By technological optimism we mean a systematic perception on the part of scientific and technical professionals that solutions to problems can be crafted through the straightforward administration of readily available technologies. It is, in Leon Lindberg's words, "an overwhelming faith in progress . . . that admits of few limitations to the ability of scientific knowledge to solve problems. Obviously, much of this optimism is justified by past experience. Scientists and engineers have solved a wide range of problems and have fundamentally altered modern society. However, should this faith be too rigidly held or if it is misplaced, then serious distortions can arise. In particular, there is a tendency among those gripped by technological optimism to discount substantially aspects of problemsolving which are not technological. [8]This proclivity can lead them to misspecify and misconstrue the character of the problem and to adopt policies that prove to be inadequate. The evolution of waste management policy provides a striking illustration of both the sense of technological optimism and its often accompanying tendency to discount the nontechnical components of problemsolving.

For at least 25 years, the nuclear developers maintained that radioactive waste management was an easily solved problem; by extension, it was also one that could be disaggregated and ignored until a system was actually required. A plethora of examples document the policymakers' sense of technological optimism. We cite just a few. One manager in the Division of Reactor Development and Technology testified before the Joint Committee on Atomic Energy ~CAE) in 1959:

> Although one has to be careful to distinguish between aspiration, reality, and speculation, it is my strong feeling that the development program has thus far found solutions to some of the waste problems and at least indications of solutions to others. [10]

Even the most visible failure in waste management history, the Lyons project, was seen as technically feasible by program personnel. The Oak Ridge engineer in charge of that effort was asked whether the laboratory could have handled the problems which arose in Kansas. He replied, "Of course, it was technologically possible. [1] One executive in charge of waste management development remarked: "The easiest part of the reactor business is the waste management portion. I can't believe that it has ended up as it has. '[12]The Director of the Division of Waste Management reflected official attitudes when he told the American Nuclear Society: "We do have today, in the retrievable surface storage facility, the answers needed for safe management of commercial high-level radioactive waste. [13]

In sum, one gets a strong impression from reading the public record and from talking with former AEC personnel that, if they had just been given enough money and had been left alone, they could and would have solved the "problem" expeditiously and to virtually everyone's satisfaction.

Interestingly, this position was held despite repeated technical setbacks in a number of efforts to manage the byproducts of nuclear fission. The storage of military wastes at Hanford has been plagued with numerous problems. Tanks expected to hold the liquid waste for 50 to 100 years have corroded and leaked after less than 25.14 Although the waste stored at the Savannah River facility have not leaked into the environment, plans to

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‘Confidential interview with author, 1975.

[6]Confidential interview *with* author, 1976.

‘Confidential interview with author, 1975.

[8]Leon Lindberg, "Energy Politics and the Politics of Economic Development, 1976, p. 29.

‘See, Ida Hoos, "The Credibility Issue, '' in W. P. Bishop, et al., Essays *on Issues Relevant to the Regulation of Radioactive Waste Management, NUREG-0412,* U.S. Nuclear Regulatory Commission, 1978, for a good discussion of this point.

[10]U.S. Congress, Joint Committee on Atomic Energy, hearings, *Industrial Radioactive Waste Disposal,* 86th Cong., 1st sess. (Washington, D.C.: U.S. Government Printing Office, 1959), pp. 992-993.

[11]Confidential interview with **author,** 1975.

‘Ibid.

[13]Speech by Frank Pittman to the American Nuclear **Society,** NOV. 16, 1972. Reprinted in Atomic Energy Commission Press Release S-18-72, p. 2.

[14]See *Environmental Impact Statement, Waste Management Operation% Hanford Reservation, Richland, Washington,* WASH- 1538, U.S. Atomic Energy Commission, 1974.

dispose of the material in the bedrock underlying the plant have not been consummated in part because of potential technical difficulties.[15] The legacy of the Nuclear Fuel Service operation, 640,000 gallons of waste in upper New York State, will cost nearly a half billion dollars to dispose of. The attempt to build a repository at Lyons failed in part because it was too hastily conceived and designed. Low-level wastes have migrated from their burial sites at Maxey Flats, Ky., despite repeated predictions that such movements were physically impossible.[16]

Moreover, the sense of technological optimism was maintained despite the fact that past technological approaches to what must be regarded as a long-term problem have proven to be only temporary stopgaps. The experience at Hanford illustrates that point. To cope with the leakage from the corroding tanks, a decision was made in 1965 to evaporate completely the waste solutions; the resulting salt cake not only would not leak, but also it would seal up any holes in the tank. Yet, many knowledgeable people agree with the Natural Resources Defense Council’s observation that:

> Eliminating the excess liquid has to a great extent also ended [the government’s] ability to remove the waste from the tanks since as damp solids the waste can no longer be pumped hydraulically out of the tanks. Moreover, liquids cannot be reintroduced in too many of the tanks to resuspend the waste since to do so would almost certainly result in substantial leaks to the ground.[17]

While the alternative of mining the waste out does exist, that technique is beset with a number of difficulties: a remote control system for mining would have to be developed; efforts would have to be made to reduce airborne releases; and the material is difficult to deal with physically: thus, the record suggests that past technical efforts have at least occasionally complicated matters for the present and have engendered problems for the future.

No force foreordained this phenomenon of technological optimism. Rather it was something that appears to have evolved and to have been institutionalized. Indeed, as early as 1955, AEC had not become overly sanguine. For instance, one individual from the Division of Reactor Development and Technology told the first meeting of the National Academy of Science’s (NAS) Advisory Committee on Waste Disposal:

> To some extent because of our geographically isolated locations (such as Hanford), it has been possible to sweep the problem under the rug, so to speak. But those of us who are close to it are convinced we must face up to the fact that we are confronted with a real problem . . . Looking backward we know of the mistakes that many industries made in assuming that the disposal of waste was simply a back-door problem that any one could handle. [18]

At the same time, his colleague, who 4 years later, would become so optimistic in testifying before the JCAE, noted: “I certainly hope I can disabuse you of the idea that we have any solution that will solve the problems of waste disposal. “[19] Yet, if that NAS study began on a note of caution, it ultimately provided the major support for the technological optimism that developed in the agency. Although the writers of the NAS report were careful to note the need for further research, they stated categorically that “the committee is convinced that radioactive waste can be disposed of safely in a variety of ways and in a large number of sites in the United States. “2° Further, they stated that “disposal in salt was the most promising method for the near future. ’[21] The consequences of such judgments were great. As someone who has been in the waste management program for a number of years put it, “The NAS report did instill a sense of complacency in the minds of the people dealing with waste management. Because of it, we felt that a solution would be available whenever we needed it. ’[22]

The Joint Committee itself also played an important role in institutionalizing the sense of technological optimism. In extensive hearings held in 1959, JCAE heard one expert after another from AEC, from the national laboratories, from academia, and from industry testify that a technological solution to the waste management problem was possible.[23] Once that technological optimism received the imprimatur of the Joint Committee, JCAE promptly dropped the subject and, for all practical purposes, never returned to it for another 16 years.

The cumulative impact of the way the NAS report was interpreted and the Joint Committee hearings was to legitimize a certain perspective. An illusion of certainty was created where, in reality, it did not exist. Over the years, the sense of technological optimism embedded itself in the attitudes and thoughts of important agency policymakers. It became, in a sense, an official doctrine at AEC. There is no evidence that its validity was ever seriously questioned until the mi&1970’s. This optimism facilitated fragmentation by lulling policymakers; agency personnel never fully recognized that they might create in a sequential, in-

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[15] *Alternative Processes for Managing Existing Commercial High-Level Radioactive Wastes*, NUREG-0043, U.S. Nuclear Regulatory Commission, 1976, p. 12.

16&, *Improvements* N&din *the Land Disposal of Radioactive Wastes—A problem of Centuries, RED-76-54* (Washington, D. C.: U.S. Congress, General Accounting Office, 1976).

[17] Natural Resources Defense Council, ‘‘Memorandum and points of Authorities in Support of the NRC Licensing of the ERDA’s High-Level Waste Storage Facilities Under the Energy Reorganization Act of 1974, ” p. 18.

[18] National Academy of Sciences/National Research Council, The *Disposal of Radioactive Waste on Land, 1957*, pp. 16-17.

[19] Ibid., p. 34.

‘“Ibid., p. 3.

‘¹Ibid., p. 6.

[22] Confidential interview with author, 1974.

[23] Ibid.

cremental fashion an elaborate technological structure, civilian nuclear power, only to find that the last pieces could not be made to fit. The difficulties of integrating the whole were systematically underestimated.

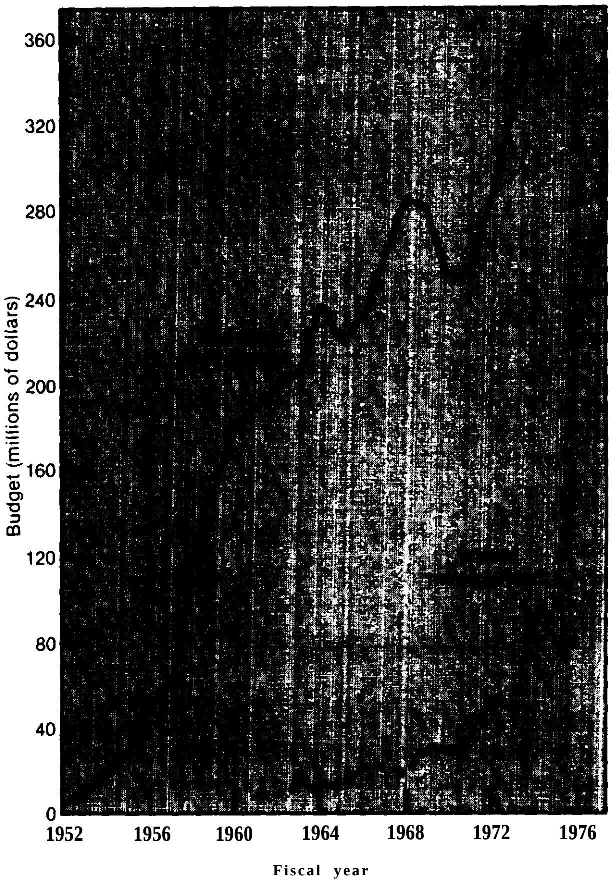
Furthermore, it seems likely that this sense of technological optimism influenced the manner in which decisionmakers conceptualized the issue of waste management. In particular, the lack of attention given to the nontechnical dimensions of policy prior to the mid-1970's may have resulted from a belief that the problem was so readily technically solvable. In such a case, it is understandable that AEC managers came to view the technology as virtually self-implementing. Only within the last 6 or 7 years has the recognition grown that the nontechnical or institutional aspects of waste management need to be addressed as thoroughly and intensively as the technical ones.[24]

Thus, during the formative years of waste management policymaking, 1945 to 1975, the issue was never given a very high priority by the AEC leadership. Waste was unglamorous; the management of it was not a pressing problem and could therefore be postponed; such a postponement hardly seemed ill-advised at the time because a firm belief prevailed in the nuclear power community that once a need arose, the problem would yield to some readily envisioned, self-implementing technical solution.

The consequences of this state of affairs were twofold. First, budgetary commitments for waste management, the program's staff of life, were minuscule, particularly when compared to funds expended for reactor development. (See fig. A-1 and also table A-1 which detail the allocations for waste management up to the present time.) Those low budgets severely constrained problemsolving as personnel were forced to make do. Second, the years of relative neglect made it harder to respond to rapidly growing external concerns about the adequacy of the waste management program. The organizational and technical infrastructure had not been well established prior to the mid- 1970's. As a result, AEC and its successors found themselves in a constant struggle to catch up. When the program appeared to falter, its credibility was challenged. That, in turn, created a situation in which efforts to find solutions were undermined.

In describing the context of policymaking we refrain from critically judging the choices made, even though in retrospect some of those decisions proved to be unfortunate. We do so—and suggest that others do so as well—because, at the time the choices were made, they appeared at least reasonable and, perhaps, given the constraints at work, the most appropriate possible. Thus, while one can properly be concerned about the lack of progress in waste management, one ought not to denigrate those—at all levels—who worked this problem in the past.

Figure A-1.—Expenditure for Reactor Development Compared With Expenditures for Waste Management



Having established the context of policymaking that prevailed up until 1975, we must note that it has changed dramatically over the last half decade. Whereas AEC did not even have a separate organizational structure with its own budget responsible for waste management prior to 1972, now DOE has an Office of Nuclear Waste Management headed by the Deputy Assistant Secretary. Funding for commercial waste management is now over 100 times greater than it was a decade ago. During the Carter administration top officials at DOE maintained that, aside from the strategic petroleum reserve, waste management had captured highest priority. And while decisionmakers over the last 5 years still strongly believe that managing radioactive waste is not

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[24] See for instance, W. p. Bishop, et al., *Proposed Goals for Radioactive Waste Management*, NUREG-0300, U.S. Nuclear Regulatory Commission, 1978, and *proceedings of Conference on Public Policy* Issues in Nuclear Waste *Management, 1976.*

Table A= I.—Waste Management Costs
(dollars in thousands)

Fiscal year	Commercial	Defense
1960 and prior		$ 125,772
1961		8,573
1962		8,940
1963		8,972
1964		11,702
1965		9,492
1966		14,953
1967		17,725
1968		21,020
1969		26,421
1970		27,526
1971		32,017
1972	$ 1,704	44,653
1973	3,750	44,570
1974	6,215	54,998
1975	10,263	83,521
1976 and TQ....	16,632	141,203
1977	67,087	162,969
1978	123,236	234,362
1979	179,753	296,899
1980	207,192	313,864
1961	256,343	336,628
1982	317,473	392,000
Total	$1,189,648	$2,418,776

a difficult technical problem, their current optimism has not led them to discount the other dimensions of policy and, perhaps more significantly, appears to be founded on a firmer technical base.

As the reader digests the next sections dealing with the substance of problem-solving, he should keep in mind what the context of decisionmaking was and how that context influenced the action taken.

Defining Radioactive Waste

Radioactive waste comes in a variety of forms; they include uranium mill tailings, low-level waste derived from industrial, institutional, power generating, and military sources, and waste derived from the decontamination and decommissioning of nuclear facilities. While all those forms create some health hazard and therefore must be managed with care, this paper shall concentrate almost exclusively on two other types: high-level and transuranic contaminated waste.

During the early years of the nuclear endeavor, prior to 1970, only low- and high-level waste were distinguished; the former variety had to be kept strictly isolated and contained while the latter could be placed into the environment under conditions of lower constraint. More precisely, AEC in 1957 defined high-level waste to refer to material which "emitted radiation so strong as to materially reduce the time a person can be near the radiating body. "[25]In practice,that meant that are lease of two or more roentgens per hour arbitrarily qualified material to declassified as high-level waste. Ten years later, that definition was refined to mean material "which, by virtue of its radio-nuclear concentration, half life, and biological significance, requires perpetual isolation from the biosphere."[26]

Some material, such as the byproducts of reprocessing military fuel and the postfission products of commercial power reactors, clearly falls under these radiological definitions of high-level waste. Classifying other material, however, is somewhat more complicated. For instance, material contaminated with transuranic elements, transuranic waste, initially was interred, along with low-level waste, in shallow land burial sites. In the late 1960's, AEC decided to halt that practice and segregate its own transuranic waste for ultimate transfer to and disposal in a geologic repository. In 1974, the agency proposed that commercial waste possessing transuranic activity of greater than 10 nanocuries per gram be treated the same as commission-generated transuranic material .[27] Although that regulation was never adopted and thus no formal definition of transuranic waste is available, there seems to be a fair amount of agreement that transuranic waste, however ultimately defined, will eventually be disposed of in a manner similar to that of high-level waste. The Nuclear Regulatory Commission (NRC) is currently carrying out a study to determine whether other radionuclides, hitherto treated as low-level wastes, should, like transuranic waste, become subject to more stringent management controls.[28]

The very idea of waste connotes something that is valueless. The military high-level waste conforms as readily to this ordinary language meaning of the term as it does to the radiological definition. The material that emerges from a reprocessing plant at the Hanford or Savannah River facilities is economically worthless. The situation, however, with regard to the postfission products of nuclear reactors is somewhat more complex and contentious.

From the earliest days of AEC reactor development program, the operating assumption was that commercial spent fuel would be reprocessed and its residual uranium and plutonium recycled as fuel. As the Director of Reactor Development wrote Commissioner Libby in 1957, employing this technological alternative would

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[25]" Handling and Disposal of Radioactive Waste, " AEC 180/6, June 14, 1957, p. 10,

[26]Minutes of Atomic Energy Commission Meeting 2373, June 3, 1969, p.13.

[27]See, *Management of* Commercial High *Level and Transuranium-Contaminated Radioactive Waste,* Draft EIS, WASH-1539, U.S. Atomic Energy Commission, Washington, D. C., 1974, pp. 2.4-1—2.4-17.

[28]See, A *Classification* System *for Radioactive Waste Disposal— What Waste Goes* Where? NUREG-0456, U.S. Nuclear Regulatory Commission, Washington, D. C., 1978.

‘ ‘increase utilization of uranium resources and lower fuel costs. “2[9] (It would also provide the not inconsiderable benefit of facilitating the sale of U.S. reactors abroad.) High-level waste then became whatever was left after reprocessing and recycle. Indeed, the first formal definition adopted by AEC in 1970 held that commercial high-level wastes were “those aqueous wastes resulting from the operation of the first cycle solvent extraction system, or equivalent and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuels. ’[30]

Given the view that reprocessing would be economically advantageous, that definition seemed quite consistent with the ordinary language connotations of the term waste. Within the next 5 years, however, the logic behind AEC’S 1970 definition of high-level waste came under challenge. For the ordinary language connotations of waste as something valueless did not seem to apply to reprocessed commercial material alone.

The definitional dilemmas arose because earlier assumptions about the costs of reprocessing no longer seemed to hold. The first reprocessing plant, operated by Nuclear Fuel Services, initially charged a fee that was substantially lower than what the next generation of facilities would have to impose. 31 The increase was believed to be so great that arguments were advanced suggesting that reprocessing might not be economically advantageous at all. Robert Fri, Deputy Administrator of the Energy Research and Development Administration (ERDA), informed President Ford that for the United States, “the economics of the [reprocessing] technology are uncertain, and even if favorable, would produce only about a 2-percent reduction in the cost of generating [nuclear] electricity”[32] (emphasis added). Thus, the plutonium and uranium components, to which value had been attributed, might not, after all, be valuable.

The economics of reprocessing were a major element considered in the plutonium recycle rulemaking hearings Generic Environmental Statement on Mixed Oxide Fuel (GESMO) conducted by NRC. The Commission’s staff, somewhat more cautious than Fri, predicted a discounted benefit of $3.2 billion over a quarter century for a reprocessing/recycle option compared to the ‘‘throw-away’ fuel cycle.[33] This is an 8 percent fuel cost advantage, but less than a 1 percent advantage in total electrical costs. Obviously, substantial uncertainties are associated with those predictions. But what is significant is that the logic for defining high-level radioactive commercial waste was seriously and officially undermined; unreprocessed spent fuel rods could now satisfy both the ordinary language and radiological definitions of waste.

The GESMO analysis is notable in an ironic sense as well. Whereas the definition of waste was initially a byproduct of an intuitive commitment to reprocessing and recycling, now reprocessing and recycling were being advocated, in large degree, on the basis of waste management considerations: 40 percent of the economic advantage of that fuel-cycle option derived from savings in the costs of waste storage and disposal .34 Moreover, arguments were made within NRC to continue to push recycle aggressively in terms of the waste management implications of failing to do so.[35])

The shifting definition of commercial high-level waste had some pragmatic consequences. When, in 1970, AEC tied the definition to a particular fuel cycle, they set off a critical sequence of events. For once the presumption is made that spent fuel contained valuable components, there are strong economic incentives to extract those components as rapidly as possible. At the same time, safety considerations dictate that large volumes of the residual material should not accumulate. The combination of those two factors led AEC, at the same time it released its definition, to promulgate a regulation requiring that high-level commercial waste be transferred to the Government within 10 years from the time irradiated fuel rods were removed from the reactor [36] When AEC acted, this requirement did not appear to pose difficulties as a repository at Lyons, Kans., was being developed. When that effort was terminated, however, the strong need arose to have an alternative available to receive the waste from reprocessing plants. In particular, the decision to construct a retrievable surface storage facility (RSSF) can be directly traced to the need to satisfy that regulatory exigency .37

As spent fuel emerged more clearly as a possible category of high-level waste, policymakers had to reorient some of their programs. NRC, for instance, was in the midst of the “S-3’ hearings on the environmental effects of reprocessing and waste management. The definitional changes forced new analyses to be performed and added to the regulators’ uncertainty about whether their actions would be sustained in court. In addition, deferral of reprocessing increased pressure on utilities to find

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“’’Plutonium Recycle Program at Hanford, ” AEC-960, Mar. 14, 1957, p. 1.

[30] App. F, 10 *Code of Federal Regulations*, pt 50.

[31] See, for example, *Final* Generic *Environmental Statement on the Use of Recycled Plutonium in Mixed Oxide* Fuel *in Light Water Cooled Reactors* (GESMO), NUREG-0002, U.S. Nuclear Regulatory Commission, 1976, pp. xi-19—xi-23.

[32] Memorandum to the President from Robert Fri, Sept. 7, 1976, p. 19.

[33] *GESMO*, Op. cit. p. ES-16. See also Spurgeon Keeny, Jr., et al., *Nuclear Power Issues and Choices* (Cambridge, *Mass.:* Ballinger, *1977)*, p. 323.

[34] *GESMO*, Op. cit., p. 11-78.

[35] ‘‘Pu Recycle Issue, ” SECY-75-37, Feb. 19, 1975, p. 8.

[36] See app. F, 10 CFR 50.

[37] ’’ Management of Commercial High Level Radioactive Wastes, ” SECY-2371, Mar. 17, 1972, p. 13.

space to store spent fuel assemblies. Over three times as much room would be required. 38 The Carter administration’s decision to request authority to construct an away-from-reactor facility was a response to that perceived problem.

But the major significant consequence of the shift was the injection of a novel issue into the waste management debate: could spent fuel be disposed of as safely and efficiently as waste from a reprocessing plant? The GESMO analysis answered that question affwmatively and concluded that there is “no clear preference for any specific fuel-cycle option based on radioactive waste management considerations. ’[39] But others, particularly advocates from the nuclear industry and some geologists, were not as persuaded. They argued that differences in volume, heat generation, amount of long-lived toxic radionuclides, and homogeneity of chemical composition all worked to increase the ease and lower the risk of disposing reprocessed waste. This controversy raged intensely for a time. There appears to be an emerging, although not complete, technical consensus within this country that “considerations of the management of [high-level waste] do not put significant constraints upon choices among various fuel cycles. ’[40] That view has recently been supported in the report of the International Nuclear Fuel Cycle Evaluation study group .41

Storing Radioactive Waste

Early records of waste management policymaking blur the conceptual difference between storing and disposing of radioactive waste. Over the years seemingly more precise conceptual distinctions emerged even though semantic confusion persists. Nevertheless, some definitional ambiguity still remains. The purpose of this section is to clarify the meaning of the two terms, to show how thinking about storage has evolved, and to specify some remaining policy dilemmas dealing with waste storage. We shall then consider the issues surrounding radioactive waste disposal in the next three sections.

The connotations associated with the terms storage and disposal can be misleading. Storage is usually linked to temporariness, disposal with permanence. Phrases such as ‘‘interim’ are connected to the former term while “ultimate’ and “final’ are associated with the latter. It is quite possible for the same technological system to be viewed by some individuals as an interim measure while others see it as providing a final resting spot for waste. Thus, the designation of a system depends mainly on what can be done with it sometime in the future, a fate that cannot be forecast at the start with complete certainty. A more conceptually clear way to distinguish storage from disposal is based on the degree of effort that must be exerted to gain access to and active control over the waste material. At the extremes, spent fuel management at the reactor would be an example of storage while extraterrestrial shipment or transmutation would be instances of disposal. In between, all other technical approaches must be viewed as possessing some mixture of storage and disposal characteristics. For instance, NRC’s draft requirement that a geologic repository be designed to facilitate the retrieval of the waste for 50 years after emplacement operations cease transforms geologic “disposal” into an elaborate method of storage. [42] For simplicity sake, we shall call those approaches which require at least as much effort to gain access to and control over the waste as burial in geologic formations without provisions for retrievability “disposal options. Those approaches requiring less exertion will be termed “storage options. ” This shorthand should not encourage the reader to forget that a continuous range exists between the endpoints of “storage” and “disposal.”

This country’s first large-scale excursion into waste management centered on developing storage systems. The vast tank farms at the Hanford Reservation, as we noted above, were established to hold the liquid waste produced in conjunction with the nuclear weapons program. The functions of the system were ambiguous at the time they were created and, to some extent, remain so today. There is some evidence to suggest that those involved at Hanford, particularly during the pre-1970 period, viewed the tanks, or some relatively minor modification of them, as a perfectly viable final approach to managing the wastes. [43] Indeed, the view is advanced in some early documents that the tanks would maintain their integrity for hundreds of years, just the length of time needed for the two biggest “problem isotopes, strontium and cesium, to decay .44 Certainly, this view of perpetual tank storage was the one which prevailed in the design of the commercial waste management system used at the Nuclear Fuel Service’s (NFS) reprocessing plant .45

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[39] Ibid., p. iv-H6.

[40] L. Charles Hebel, et al., *Report to the American Physical Society by the Study Group on Nuclear Fuel Cycles and Waste Management* (APS Report), *Report of Modern Physics 50,* January 1978, p. 5107.

[41] See *International Nuclear Fuel Cycle Evaluation,* IAEA, Vienna, Austria, 1980. ‘

[42] *Federal* Register, Mar. 5, 1981.

[43] For examples of the ambiguity, compare Atomic Energy Commission 180/5, “Disposal of Radioactive Wastes, ” Mar. 30, 1956 with Atomic Energy Commission 180/6.

[44] See, “Hanford’s Highly Radioactive Waste Management Program, ” AEC 180/30, Apr. 5, 1968, pp. 6-7.

[45] See U.S. Congress, Joint Committee on Atomic Energy, hearings, *Chemical Reprocessing Plant,* 88th Cong., 1st sess. (Washington, D. C.: U.S. Government Printing Office, 1963).

By 1956, however, another position began to gain currency within AEC. Those who took that new tack argued that tank storage was not the "ultimate solution" to the waste management problem . . . if only because it was too expensive over the long run.[46] Instead, they advocated a robust research program to find a technical option that could be employed *to* manage newly created waste material. Thus, rather than being a final measure, tank storage would simply serve as an interim approach pending the discovery of something better.

There were a number of AEC staff and policymakers who saw the storage system serving a third function: a reservoir containing materials of economic importance. Efforts were initiated to extract from the waste soup radionuclides that were commercially valuable. Strontium and cesium would be employed as heat sources; cesium would be used in a project to irradiate foods; the heavy metals would be destined for industrial applications. [47] In his way, some of the costs of the waste management program might be offset. There was sufficient enthusiasm for this approach in the late 1960's that one firm reached an agreement with AEC to build a fission product extraction plant at Hanford. But before construction began the economics of the endeavor turned sour and the company canceled its plans. Nevertheless, the idea of fission product recovery of commercially valuable material would not die easily. As late as 1975, JCAE was pushing the concept.[48] Even today, some people still hope to see some commercial venture to utilize fission products.

The next major initiative in the waste management program was the effort to develop a disposal facility at Lyons, Kans. A combination of technical weaknesses and a lack of attention to the institutional aspects of the project contributed to its early and painful demise. AEC, thus, found itself in early 1972 without a repository and without a fallback plan to find another site for one in the near term.

AEC response was to propose constructing a series of aboveground engineered structures—mausolea—which would be used to store solidified, reprocessed waste from the commercial sector. [49] The explicit rationale for this undertaking presented to AEC was:[50]

> If the problems of gaining public acceptance of the concepts of storage [sic] in geological formations cannot be overcome in the near future, an available option is retrievable storage in carefully engineered man-made structures and acceptance of the idea that man must maintain close control over the waste so stored at least until geologic storage [sic] becomes acceptable or until development of new technology opens up new approaches not now practical.

Storage in RSSF would be used as an interim approach pending a more hospitable political environment.

Unfortunately, AEC took other actions over the next 2 years which, at the very least, sent a set of mixed signals to those interested in waste management policy. Perhaps because fiscal year 1975 was a tight budget year, AEC had to severely cut back its expenditures devoted to advancing its capabilities for geological disposal or for discovering new alternative technologies. That circumstance left the impression in the minds of some concerned individuals that the RSSF'S function could very well evolve into one of final disposition rather than the interim one which AEC asserted. That was precisely the critique of the RSSF leveled by the Environmental Protection Agency (EPA):

> A major concern in employing the RSSF concept is the possibility that economic factors could later dictate utilization of the facility as a permanent repository, contrary to the stated intent to make the RSSF interim in nature . . . [I]t is important that [environmental factors] never be allowed to become secondary to economic factors in the decision making process. Vigorous and timely pursuit of ultimate disposal techniques would assist in negating such a possibility . . . However, the draft statement does not contain an adequate description of a program to develop such a disposal system nor does it reflect either the priority given to programs by the AEC nor an indication of the resources required .[51]

More than any other single criticism, the one advanced by EPA and supported by other commentators provide the coup de grace for the RSSF concept. In this instance, it was clear that it was unacceptable to proceed with a storage system unless there were unambiguous assurances that the system would not degenerate into a final disposing spot for the waste.

Since the cancellation of the RSSF, Federal activity has concentrated on the development of disposal technologies, particularly mined geologic repositories. A number of generic studies have been undertaken and exploration of specific sites commenced. But because of the. program's relatively late start and its slow progress and because of possible lengthy delays in the start of commercial reprocessing, concerns arose as early as 1975 that a number of operating reactors would run out of room to store their discharged spent fuel onsite.[52] Should that occur and if there were no alternative locations to place the material, then the reactor would be

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[46] Atomic Energy Commission 180/5, op, Cit., p. 5.

+7 Memorandum, Frank Pittman to James Ramey, Feb. 25, 1965, pp. 7-8.

[48] This matter arose during hearings on the Atomic Energy Commission's fiscal year 1976 budget.

[49] See WASH-1539.

[50] " High Level Waste Management, SECY-2271, Jan. 25, 1972, p. 3.

[51] EPA response to WASH-1 539, No v. 15, 1974, p. 2.

[52] *LWR Spent Fuel Disposition Capabilities, 1975-1984, ERDA-25, Energy* Research and Development Administration, 1975.

forced to shut down. Between 1975 and 1977, the private sector floated proposals to construct large-scale facilities to hold excess spent fuel from utilities. Yet, for a variety of reasons, many unclear to this day, those proposals never reached fruition.

It was in this context that the newly elected Carter administration announced its spent fuel policy in October 1977.[53] Under it, title to the spent fuel would be transferred to the U.S. Government. The fuel would be transported to a Government-approved away-from-reactor site at the utility's expense. A one-time fee would be paid by the utility that would cover the Government's costs of storage and disposal. In addition, the administration expressed a willingness to accept limited amounts of foreign spent fuel for storage and disposal if such an action contributed to the achievement of the country's nonproliferation goals. At the time this policy was first articulated, many of its modalities and logistics were unsettled. The administration, for instance, did not necessarily propose to construct a new storage facility on its own. It was prepared to contract with the private sector for storage services.

Thus, the away-from-reactor storage proposal was initially designed to serve four different functions. It prevented the shutdown of reactors pending repository development; it would provide time for the geologic disposal program to mature; it would provide some foreign countries at least a limited incentive to forego fuel reprocessing thereby reducing the spread of nuclear arms; it would provide a means of conserving potentially valuable material since the plutonium and uranium in the spent fuel would be accessible should reprocessing ever be permitted and become economically viable. Later on, the away-from-reactor program was also advocated by those who saw a fifth function: the away-from-reactor, by relieving some of the pressures on the nuclear industry, would reduce the likelihood that the industry might use its large political clout to force a premature decision on a geologic disposal plan. Finally, the administration carefully distinguished its policy from the RSSF project. Not only did it announce that disposal remained a high priority, but it committed substantial resources toward that end. It should be noted, however, that those actions did not deter critics who maintained that an away-from-reactor would also end up as the final resting place for the stored waste either because of the short-term economics or because DOE would lose its incentive to develop repositories.

The administration's initiative to involve the public sector in the provisions of storage facilities placed the issue of waste management on Congress' legislative agenda after a hiatus of nearly 5 years. A plethora of bills were introduced dealing with a wide range of waste management issues. In July 1980, the Senate passed S. 2189, which, in many respects, marked an abrupt change from the policies that had evolved over the last decade.

In particular, the bill blurred the conceptual distinction between storage and disposal. The bill defined "disposal' ' to include the:

> . . . long-term isolation of material, including long-term monitored storage which permits retrieval of the material stored.[54]

Moreover, it provided for the construction of a "disposal" facility that would:

> . . . permit continuous monitoring, management, and maintenance of the spent fuel and high level radioactive waste for the foreseeable future, allow for the ready retrieval of any spent fuel and high level radioactive waste for further processing or disposal by an alternative method, and safely contain such high level radioactive waste and spent fuel so long as may be necessary, by means of maintenance, including, but not limited to, replacement of such a facility.[55]

That section had the effect of radically redefining the idea of disposal. Although geologic means could still be pursued, indeed the bill called for that program's acceleration and a demonstration repository, mined facilities were no longer to be seen as the dominant technique of disposal. The Federal Government's obligations in that regard could be met by the construction, monitoring, and continuous replacement of a set of mausolea. In fact, the bill sanctioned a return to an RSSF-like approach.

Senate bill S. 2189 viewed the function of storage as essentially twofold: a means of preserving options to protect the resource value of the spent fuel and a method of postponing, perhaps forever, commitment to a technique of more secure disposal. It was that last vision that elicited the most hostile response. Critics maintained that the bill, by diluting the commitment to disposal, would permit an inequitable transfer of risk from this generation to generations in the future. The House of Representatives passed a bill more responsive to those concerns. And despite last-minute, strenuous efforts to compromise the two versions, no mutually acceptable legislation could be hammered out. The 96th Congress adjourned with the issue of storage still unresolved. The new Reagan administration abandoned the away-from-reactor storage proposal, believing that the private sector ought to tend to the storage of spent reactor fuel.

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[53] *DOE Information Bulletin,* R-77-017, Oct.18,1977.

S+ Senate Bill 2189, sec. 201 (3).

[53] 1 bid., sec. 402 (b).

Utilizing Knowledge of the Earth Sciences in Developing a Waste Management Program

Since the late 1950's, when the policy was informally adopted of disposing of at least the high-level waste from the commercial sector, the front running technical strategy has been emplacement in repositories mined by conventional methods. At a very early stage, earth scientists and mining engineers were involved in conceptually crafting the AEC waste management program. Those same professionals have intermittantly provided guidance to AEC and its successor agencies over the last quarter century. In this section, we shall explore how the basic scientific and technological knowledge influenced the design of the waste management program. We shall in particular note how, as the program evolved, earth science became a more central element of the effort and how relatively simple—but elegant—earth science conceptions were displaced by more complex ones.

The first major involvement of earth scientists to consider the issue of waste disposal began in February 1955. Then AEC contracted with NAS to provide advice on how to structure the research that could establish the scientific basis of a waste management program. NAS appointed an eight-man committee of prominent geologists, hydrologists, and geophysicists. The group met several times and convened a major conference on the question at Princeton University during September 1955. Two years later, the committee issued its first report, one which we noted above was extremely influential in orienting waste management policy for two decades.[56]

The problem the committee addressed was, in many repects, unprecedented: how to design a mechanism for isolating highly toxic radionuclides from the biosphere for long, possibly geologic, periods of time. At the time its deliberations began, the group took as a given the fact that the waste materials would be dissolved, at relatively low concentrations, in some liquid. This constraint strongly affected the way the committee proceeded to puzzle through the problem. In particular, ***several*** alternatives were quickly discarded, The use of granite and other crystalline rock quarries was discounted because of the near impossibility of sealing the facility against leaks. The use of permeable noncrystalline rocks such as sandstone and limestone by themselves was precluded for similar reasons. The uncertainties of sealing nonpermeable materials such as clay and shales seemed too formidable. Other options, such as injection of the waste into deeply lying porous media interstratified with impermeable beds, were deemed to be feasible in principle but so plagued with significant problems that they were impractical in the short run.[57]

One technique did, however, strike the committee as rather promising. It involved the use of salt, either bedded or domed, cavities: "Abandoned salt mines or cavities especially mined to hold waste are, in essence, long-enduring tanks. "5[8] What made salt the appropriate and in some sense the elegant solution were two factors. First, water will not pass through a relatively stable salt formation to carry away the waste. Second, should any fractures arise in the salt, they would soon be self-sealing because of the plastic flow properties of the material at typical repository depths. The NAS committee believed it had found an autonomous mechanism, based on immutable physical principles, for ensuring that the toxic waste would be reliably isolated for thousands of years.

It is essential to understand the premises behind the committee's espousal of salt. The committee's position was founded on the assumption which the group explicitly recognized required substantiation, that the material's chemical and physical properties would not be radically altered when the salt was exposed to the heat and radiation generated by the waste. If that assumption held, then all that was necessary was to find a suitable salt formation, dig a hole, backfill it with salt, and walk away.

During the next 4 years, small-scale research projects were initiated to test the validity of the committee's assumption. Those investigations were "encouraging, but there remained a variety of difficulties which, in the words of one report, were "unique to liquid waste disposal. "5[9]Cavity alterations and radiolytic reactions were observed. And while the technical operatives expressed optimism that those obstacles would be overcome, it became evident that the salt concept had not been validated.

As the 1960's began, substantial alterations in fuel reprocessing technology were being made, the most important of which involved a twentyfold reduction in the volume of liquid waste. That breakthrough, while substantially increasing the waste's heat and radiation density, facilitated transforming the material into a solid form. That prospect, in turn, redirected AEC'S fledgling research program. AEC contractors, urged on by the NAS committee, set out to examine the effect of dry packaged radioactive wastes on salt. Therein lie the origins of the first major in situ experiments—called

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[56] NAS/NRC, 1957, op cit.

[57] Ibid., pp. 81-103.

[58] Ibid., p. 5.

[59] R. L. Bradshaw and W. C. McClain (eds.), *Project Salt Vault: A Demonstration of the Disposal of High-Activity Solidified Wastes in Underground Salt Mines, ORNL-4555, Oak* Ridge National Laboratory, Oak Ridge, Term., 1971, p. 1.

Project Salt Vault—undertaken to obtain the data needed to design a waste repository.

To say that AEC vigorously pursued these efforts to validate the salt assumptions would vastly overstate the case. Funds to support Project Salt Vault had to be "bootlegged" from other efforts by researchers at the Oak Ridge National Laboratory. With some difficulty they put together enough resources to carry out studies in the Carey Salt Mine at Lyons, Kans., between 1965 and 1967. Fourteen irradiated fuel assemblies taken from AEC's Experimental Test Reactor were used to simulate solidified waste. The assemblies were placed in a ring-like arrangement in the floor of the mine. Furthermore, electrical heaters were installed to raise the temperature of a large quantity of salt in the central pillar in order to obtain information on its in situ structural response to heat. In spite of the rather high radiation doses to the salt and in spite of the high thermal loading, no measurable radiolytic or excessive structural effects in the salt were observed. While hardly a definitive or exhaustive test, the results of Project Salt Vault at the time did lead many in AEC to believe that the salt assumptions were largely valid.[60]

Although the AEC leadership had little enthusiasm for this experimental effort when it was first proposed or even as it was being conducted, nearly 3 years after it was concluded the undertaking took on special significance. For in 1970, AEC decided to move ahead and develop a full-scale facility at the Carey Salt Mine.[61] AEC'S managers relied heavily on the Salt Vault data to support their new initiative. Indeed, the environmental impact statement assessing the proposed Lyons repository contains no geophysical information gathered at the site after the conclusion of Salt Vault.[62]

The Kansas project was ultimately canceled because water from a nearby solution mining operation could not be easily accounted for and because it was hard to persuade critics that the roughly 20 oil and gas boreholes could be reliably plugged. The abandonment of the Carey Mine site, however, did not undermine AEC's faith in the salt assumptions. In fact, as we detail later on in this essay, the Commission quickly moved to identify other sites that might be suitable for a repository.[63] Nevertheless, it committed the preponderance of resources to searching for locations where the emplacement media would be salt. This almost single-minded preoccupation with a single geologic formation is well reflected in the comprehensive "Technical Alternatives Document" which contains essentially no information on "nonsalt" repository options.[64]

Up until this time those earth science specialists working in and for AEC, as well as those associated with the NAS'S advisory committee, were a relatively closed group. They all accepted the salt assumptions and felt comfortable with a waste management policy that was predicated on them. Over a period of nearly 20 years, that perspective has two important consequences for the orientation of AEC's research program. First, comparatively little effort was devoted to considering how the geologic environment outside of the salt formation might contribute to isolating the waste. Second, there was considerable reluctance to investigate other emplacement media as a possible alternative to salt.

By the mid-1970's, because of the abandonment of the Lyons site and because of the growing controversy over nuclear power, waste management policy became salient to a wider range of individuals, members of the general public and technical specialists alike. Many of the new participants were unable to accept the prevailing salt assumptions. At first, the criticism of the Government's waste policies came from citizen groups generally opposed to nuclear power. The salt assumptions were rejected in those criticisms as concerns were raised about brine migration, decrepitation, the problem of breccia pipes, and the corrosiveness of salt solutions, concerns which had all been considered and largely discounted by the Commission. Later on, however, more subtle challenges were advanced. These did not reject the salt assumptions but held them to be problematic and therefore urged that different technological strategies be explored.

Perhaps the earliest influential instance of the latter brand of skepticism was the report of the American Physical Society (APS) study group on nuclear fuel cycles and waste management.[66] The APS study group did not explicitly reject the salt assumptions. On several occasions the report's authors stated that there was no basis for believing that a salt repository could not be developed.[67] Yet, the conceptual thrust of the APS study was strikingly different from that which had dominated since the mid-1950's. Instead of accepting the elegant solution of a relatively isolated, autonomously self-correcting salt formation, the group stood back and focused on the larger hydrogeologic environment.

That environment was, in their view, the critical element in designing a waste disposal facility. While the behavior of the emplacement media per se was impor-

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[60] See for instance, memorandum, George Kavanagh to Commissioners, "Background Information on Long Term High-Activity Waste Management," Sept. 8, 1967, p. 2.

[61] 'Solid Radioactive Wastes: Salt Mine Storage," AEC 180/81, Apr. 23, 1970.

[62] *Radioactive* Wrote *Repository, Lyons, Kansas,* U.S. Atomic Energy Commission, Washington, D. C., 1971.

[63] 'High-Level Waste Management, SECY-2333, Feb. 24, 1972, p. 4.

[64] *Alternatives for Managing Wastes From Reactor and Post-Fission Operations in the LWR Fuel Cycle,* ERDA-76-43, Energy Research and Development Administration, Washington, D. C., 1976, pp. 24.49-24.80.

[65] "Solid Radioactive Wastes: Long-Term Storage in Central Kansas Salt Mine," AEC 180/87, June 12, 1970, p. 5.

'*American Physical Society, 1976.*

[67] See *American Physical Society,* p. S139, for example.

tant, it need not be determinative. For if sufficiently long hydrological flow paths were available and if sorptive material were present along those paths, then the requirements that the emplacement media be self-sealing and impermeable might well be superfluous.

> Based on our analysis of hydrogeologic transport we expect that the conditions that would provide for satisfactory geologic isolation of radioactive waste—i. e., a suitable groundwater environment—are present in a sufficient number of places that several acceptable sites in difi ***ferent geologic media can*** be located without difficulty in the immediate future.[68] [Emphasis in original.]

Thus, the APS report recommended that a broader program of geologic research and development be instituted.[69]

That position, on the surface, appears inconsistent with the group's unwillingness to reject the salt assumptions. After all, if those assumptions held, then substantially greater attention to geohydrology and ground water modeling would itself be superfluous. The elegant solution had not been overthrown.

What made the APS report internally consistent was the introduction of 'anthropogenic concerns. '[70] Even if the formation compensated for natural disruptions, salt, particularly domes, by its very nature was attractive to those looking for oil, gas, potash, or even a storage site. Future generations searching out those resources might inadvertently disrupt the repository and bring on "possibly serious consequences" unless the environment outside the emplacement media also contributed to the isolation of the waste. But if one considers the environment of the salt, there is no reason why the environment should not be considered for other media. In the group's view such a course would only be "prudent"—hence their conclusions and recommendations.

While the APS study did not explicitly reject the salt assumptions, another report published shortly thereafter came quite close to doing so—at least in the context of prevailing premises about repository operation. Since the early 1950's, the U.S. Geological Survey (USGS) had been supporting AEC and its successor agencies in their waste management research. In the mid-1970's the USGS involvement had begun to intensify. The two agencies' interaction was not entirely without conflict, which centered on the nuclear organization's commitment to salt. For a period of time, USGS personnel tried to reach an accommodation on that issue with those managing the waste program. Those USGS scientists, however, eventually came to believe that their concerns about salt-some of which reflected the views of nuclear opponents—were not being given proper consideration. 71

In a rare action by traditionally cautious bureaucrats, the USGS scientists publicly expressed their concerns in Circular 779: "Geologic Disposal of High-Level Radioactive Wastes—Earth Science Perspectives. "7[2] The bulk of the work engendered little controversy; the middle section, however, raised some disturbing—although not entirely novel—questions and in doing so conferred a legitimacy to those technical concerns about disposing of waste in salt which heretofore had been lacking. The USGS argument asserted that if relatively hot waste—say 5 to 10 years old—is introduced into a salt repository the potential exists for the repository to lose its integrity. That circumstance would arise because the thermal pulse would aggravate "the mechanical disturbances initiated by mining the repository and the chemical disturbances caused by the introduction of material-not in chemical equilibrium with the rock mass. '[73] Should the repository fail, the salt would not itself retard the migration of the nuclides. Thus, USGS arrived at precisely the same conclusion, although by a different and—from a policy perspective—substantively significant route, as did the APS study group.

It would be misleading to infer from this discussion that AEC and its successors were unbending in their commitment to salt. Beginning in 1973 and accelerating in the next few years, AEC and its successor agencies sponsored research in other media. 74 In 1976, ERDA announced a program to examine a variety of emplacement media to find acceptable repository sites and that the third facility might be constructed in some media other than salt.[75] Yet, if policy makers at AEC and ERDA were prepared to open the door for geologic diversity, they saw little reason to abandon the salt assumptions. However, as more and more technically competent groups" and individuals inside and outside the Government questioned the salt orthodoxy, it became clear that this fundamental earth science controversy had to be resolved. The forum for that resolution came to be the Interagency Review Group on Nuclear Waste Management (IRG) established by President Carter in April 1978.

A working subcommittee of IRG, chaired by the Office of Science and Technology Policy (OSTP), was assigned the task of crafting a paper synthesizing the status of knowledge about waste isolation using geologic repositories. [76] Representatives from DOE and USGS took an active role in the preparation of the report. The

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[68] Ibid., p. S138.

[69] Ibid., p. S7.

'"Ibid., p. S139.

[71] Confidential interviews with author, 1980.

[72] The circular was written by J. D. Bredehoeft, A. W. England, D. B. Stewart, N. J. Trask, and 1. J. Winograd.

[73] Circular 779, pp. 4-5.

[7] V3ECY-2271, p. 3.

[75] *Information From* ERDA, "ERDA Studies Geologic Formation Throughout Nation for Data on Potential Sites for Commercial Nuclear Waste Disposal, " No. 76-355, Dec. 2, 1976.

[76] *Subgroup* Report on Alternative *Technology Strategies for the Isolation of Nuclear Waste*, app. A, TID-28818 (draft), Interagency Review Group on Nuclear Waste Management, Washington, D. C., October 1978.

study underwent four major revisions over the course of slightly over 6 months. It was reviewed both by a specially appointed advisory committee and by hundreds of individuals from the earth science community.[77]

The section dealing with salt repositories in the OSTP paper represented something of a compromise between the views of DOE and USGS; in tone and thrust it was quite akin to the APS study. In essence, the OSTP document questioned, but did not overturn, the salt assumptions. At the same time, it reiterated the concerns of APS and USGS about the importance of viewing the waste isolation mechanism as an entire system of waste form, package, repository structure, and hydrogeologic environment.

The evolution of earth science perspectives from the early 1950's to the late 1970's was striking and profound. While no one dismissed out of hand the concept of a mined repository, the elegant solution of salt came to be questioned—and for some—rejected. In its place has come a more complex view of what needs to be done to ensure that waste will be reliably isolated for geologic periods of time. In the three sections that follow—site selection strategy, waste packages, and regulatory philosophy—we shall be recapitulating some of the themes raised here. For those aspects of the waste management problem came critically to depend on the status of geologic science and technology.

Developing a Search Strategy For Sites

Siting strategies fall along a conceptual continuum. A process by which sites are randomly examined until an acceptable one is found demarcates one extreme. The other end point corresponds to a strategy in which all possible sites are comprehensively compared along a variety of dimensions prior to selecting one. In the pragmatic world of seeking a location for a repository, neither extreme is appropriate. The former approach fails to take advantage of existing knowledge to eliminate a priori sites that are unsatisfactory. The latter approach is too demanding of knowledge, time, and resources. In between the two extremes, a range of "mixed" strategies do exist, and they can be distinguished in terms of how proximate they are to either end point of the continuum. Indeed, the history of site selection strategies is a chronicle of movement away from the more random end toward the more comprehensive one.

AEC's initial site selection strategy can be inferred from the process which at least tentatively selected the Carey Mine in Lyons, Kans., as the location of the country's first repository. As the reader will recall, personnel from Oak Ridge National Laboratory used that abandoned mine for experiments designed to determine the thermal and radiation effects of high-level waste on salt. They were led to that particular type of geologic formation by the strong endorsement given salt 6 years earlier by NAS.

Those involved in this Project Salt Vault recall that their efforts enjoyed the support of the local citizenry.[78] Four factors contributed to this climate of acceptance: 1) the experiment was designed from the beginning to be reversible—once it was over all the waste was completely removed; 2) consultations were held with local groups before the project began; 3) efforts were made by Oak Ridge staff personnel to conduct the studies in full view of the Kansas population; and 4) once the research started, regular tours were conducted in which the general public could visit the mine.

Project Salt Vault might have become an isolated footnote in the saga of nuclear policymaking had not two circumstances intervened. The first was a fire which occurred in 1969 at an AEC weapon's components facility in Rocky Flats, Colo. The accident gave rise to a large volume of low-level, plutonium contaminated debris. Following its standard operating procedures, the managers of Rocky Flats forwarded the waste to the National Reactor Test Station in Idaho for storage. That action outraged Idaho's political leadership who saw no reason why their State should become the dumping ground for waste created in Colorado. They acted and ultimately extracted a commitment from Chairman Seaborg that all of the waste would be removed by the end of the 1970's.[79] That pledge necessitated the construction of a disposal facility. The second circumstance, which will be discussed below, was the emerging regulatory policy on commercial waste management. That evolving policy also provided a basis for AEC to go beyond the early experimental efforts at the Kansas salt mine and to develop a repository.

Thus, confronted with the need for a repository, AEC'S siting strategy was relatively straightforward. Because of the prevailing geologic assumptions held within AEC and among its contractors, host formations other than bedded salt were not even considered. This left about 500,000 mi^2 of land overlying bedded salt within the continental United States. That area was further reduced because only salt deposits 200 ft thick and lying within 2,000 ft of the surface were deemed "to be the most desirable for the first waste repository."[80] The largest area meeting these criteria lay in central Kansas; there were two smaller areas in Michigan and one in west central New York.

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[77] 1 bid., Preface.

[78] Confidential interviews with author, 1975.

[79] Letter from Seaborg to Senators Church and Jordan, June 9, 1970.

[80] Atomic Energy Commission 190/81, Op. cit. , p. 10.

In the technical analysis provided AEC, none of the alternative sites had a clear-cut advantage in terms of their geologic characteristics although the New York location was in an area of lower tectonic stability. The Michigan site was burdened by the fact that part of it underlay metropolitan Detroit. But finally, AEC decided on the Kansas site and in particular the experimental mine in Lyons because:

1. There had been detailed information gathered on the area as part of Project Salt Vault.
2. There was a sense of confidence in receiving a "favorable reception on the part of local and state officials and private citizens. "
3. There was a recognition that necessary investigations to prove out the acceptability of the other sites would result in considerable delay "estimated on the order of two years. "[81]

The choice of the Lyons location turned out to be unfortunate. The site developers encountered several major technical problems and, as we shall point out below, substantial political controversy as well. Less than 2 years after its selection, the location was abandoned by AEC .[82]

How AEC's successors crafted a strategy for site selection in the next iteration of activity is not nearly as straightforward. What is undisputed is this chain of events. The aftermath of the Lyons endeavor had created an environment that was not conducive to further site exploration. As a result, early in 1972, USGS was asked by the AEC headquarters staff and personnel from Oak Ridge to summarize the available geologic and hydrologic knowledge of selected rock types, particularly salt, in other parts of the country and to assess their suitability for a waste repository. The USGS study identified approximately a dozen regions where candidate sites might be found. That fall, the choice was made to concentrate further exploration in the Permian basin in eastern New Mexico. The choice seems to have been made because the other regions featured salt domes and anticlines (Guld and Paradox basin) rather than bedded salt, because they were in areas of heavy population (Salina basin), or because the salt was too far underground (Williston basin) .[83]

Four candidate sites were examined in more detail and out of that investigation came the decision in favor of a site located 30 miles east of Carlsbad. Additional drilling and geophysical exploration, however, indicated that that location was unsatisfactory. Eight additional areas were studied and their consistency with eight criteria was measured. From that process emerged the site for what is currently designated the Waste Isolation Pilot Plant (WIPP), a facility now being considered as a repository for waste from the defense program .[84]

The official history of the WIPP site selection strategy leaves the reader with the impression of an entirely scientific and rational process driven simply by the force of disinterested analysis."[85] To a large degree, that is likely the case. However, that history contains at least one minor point of contention and one significant omission. The first has to do with who made the decision to focus on the Permian basin. According to the official version, "USGS and [Oak Ridge] selected Eastern New Mexico as the area in the United States best satisfying their site-selection guidelines. "[86] This was presumably at a meeting in Carlsbad in November 1972. USGS personnel who attended that meeting, however, maintain that the decision to select the Carlsbad area for further exploration was made 2 months previously by AEC headquarters staff and Oak Ridge personnel. The November meeting with USGS simply ratified the initial choice. [87]

But the omission could render the point of contention moot. Even before the technical problem which ultimately doomed the Lyons project arose, AEC officials had met with representatives from New Mexico. As a memorandum detailing that contact reports:[88]

> Their interest in obtaining a Federal waste disposal facility came from a worsening of the competitive position of the U.S. potash industry . . . as highly automated Canadian mines in rich potash seams began to come into production. This translated into a loss of jobs and a blow to the Eddy County/Lea County economy. Preliminary discussions with potash interests, the Carlsbad Chamber of Commerce and the State Department of Development indicated that there was a potential for a favorable political atmosphere. [89]

The Interagency Review Group (IRG) went on to say, however, that "there is a risk that as a result of applying nontechnical criteria first, organizational and political commitments might develop to such a degree that insufficient weight might be given to technical data developed later on. '[90]

It is fair to say that opponents of the Lyons and WIPP sites— as well as some relatively disinterested observers—believed that technical criteria had been subordinated to political and bureaucratic ones. This impression was fostered, in part, by the fact that AEC and its successor agencies made substantial public commit-

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[81] Atomic Energy Commission 180/87, op. cit., pp. 4, 16.

[82] Briefing Summary, "Program Review—High Level Waste Management, " Feb. 2, 1972.

[83] *Waste Isolation Pilot Plant, Draft Environmental Impact Statement (WIPP-DEIS), DOE/EIS-O026-D,* Department of Energy, April 1979, pp. 2-4—2-6.

[84] The announced plans for WIPP have changed repeatedly. While currently being considered for only the disposal of defense transuranic waste, at other times the disposal of defense high level waste and the possible disposal of 1,000 commercial fuel rods have been proposed.

[85] *WIPP EIS,* Op . cit., pp. 2-3—2-12.

[86] *WIPP EIS,* op. cit., p. *2-6.*

[87] Confidential interview with author, 1980.

[88] Owen Gourmley to Dorner Schueler, "Change in Exploration From Kansas to New Mexico, Feb. 1, 1979.

[89] *Subgroup Report, op. cit.,* P. *8]*

[90] Ibid.

ments to the projects and had no alternative sites available as backups. Under those circumstances it was hard to convince the skeptical that the sites would be evaluated in an objective fashion.

The siting strategy adopted up to this point, then, was closer to the random ad hoc extreme of the continuum than to the completely comprehensive end. That choice was not entirely voluntary. The preoccupation with salt reflected a limited geophysical perspective and knowledge base. Time constraints, such as those imposed by the Rocky Flats fire, the emerging regulatory changes, and the political need to show some progress in geologic disposal, ruled out a more deliberate strategy. Finally, resources were scarce; this also foreclosed a more elaborate strategy.

In truth, neither AEC policymakers nor relevant outsiders were particularly satisfied with that state of affairs. The Lyons experience had clearly indicated the pitfalls of a narrow approach to finding sites. As a result, by the mid-1970’s, AEC and later its successor, had begun to create the conditions that would allow for the adoption of a more comprehensive site selection strategy. Time pressures were dampened, at least temporarily, by the RSSF and the delays encountered with reprocessing. The Ford administration was persuaded that major funding increases in the program were required. The earth sciences knowledge base broadened as new research was undertaken.

This restructuring of circumstances was accompanied by a policy decision to expand considerably the approach to site selection.[91] There was to be a comprehensive review of underground formations throughout the United States. Thirty-six States in all were to be surveyed. Fieldwork, including core drilling, was slated to take place in at least 13 States and perhaps as many as 19, More significantly, the search, for the first time, was not to be confined to bedded salt; instead, other host rocks, such as domed salt, basalt, shale, granite, and other crystalline formations were considered. Lower than requested fundings and political objections from Governors and Senators, however, forced a retrenchment in the initial plans. While the expanded program was termed “too ambitious and not well designed for Federal/State and local government interaction, ”[92] nevertheless, as a result of this broadened policy, fieldwork was and is still being undertaken in Texas, Louisiana, Mississippi, Washington, and Nevada in search of a location for the first commercial waste repository.

This expansion of the site selection strategy yielded some important dividends. It introduced some redundancy and backup into a program sorely lacking these characteristics. It increased the public credibility of the program. It deflated concerns that a single locality had been selected as the site for the Nation’s nuclear waste.

Yet, those returns should not lead one to overestimate the degree to which the new strategy differed from its predecessor. In particular, salt was still viewed as the leading, and perhaps preferred, candidate for host rock. This predisposition, based partly on the greater depth of engineering information and partly on organizational tradition, was reflected in the new program’s assertion that the first two repositories would likely be carved in salt. In a more fundamental sense the new strategy was akin to the old in that both mandated a choice and commitment to build a repository once a satisfactory site was found and qualified. To use an analogy, both strategies adopted a decisionmaking principle similar to that used by most house sellers: as soon as an offer exceeds the threshold of “acceptability,” it is taken.

Like the order in which technical and nontechnical criteria are applied to screen sites, this decisionmaking rule need not be unsound. But if, as we shall see, there is great uncertainty and strong disagreement about what constitutes the threshold of acceptability, such a decisionmaking principle can be quite risky both scientifically and politically.

There was, in fact, increasing awareness within DOE—as well as among outsiders—of the riskiness inherent in this principle of choice. By the time the Carter administration had taken office and had completed its first assessment of the waste management program, the awareness had grown to the point where alternative selection rules were being publicly discussed. The report of the Deutch Task Force observed that “two basically different philosophical approaches were possible.[93] The first involved comparing the best salt design with the best design in another media. On that basis, the preferred media would be chosen; then several sites in that media would be considered and, presumably, the best one selected for the repository. The second approach, in essence, was the continuation of the status quo. The first satisfactory salt site would be selected and developed in a technically cautious fashion. The Deutch Task Force concluded that “the first approach [is] unnecessarily conservative’ and it favored the second .[94]

Although DOE did reconfirm its decision principle, the Deutch Report initiated a process whereby the sensibility of the philosophy was assessed. The forum for this further review was IRG. IRG assigned OSTP the responsibility of analyzing alternative technological strategies for the isolation of nuclear waste in addition to the technical report on the status of geologic knowl-

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[91] *Information From ERDA*, op. cit., Dec. 2, 1976.

[91] *Report on Task Force for Review of Nuclear Waste Management*, DOE/ER-0004 (draft), Department of Energy, Washington, D. C., February 1978, p. 12.

[93] Ibid.

[94] Ibid., p. 13.

edge. OSTP began by conceptualizing six strategies in which the first disposal mechanism was a geologic repository. (A seventh postponed the choice of option.) The six alternatives differed in the degree to which there would be intercomparisons prior to site selection. The most restrictive alternative was that of evaluating the suitability of sites on a case-by-case basis—e. g., the status quo. The broadest alternative called for comparison of several sites in several different geological environments. This broad range, it should be noted, was dictated by the technical finding, discussed above, that no particular geologic emplacement medium enjoyed a preferred position.

As the analysis got under way, the OSTP group soon concluded that the strategies which required intercomparisons possessed certain advantages over the case-by-case approach.[95] Intercomparison of sites would likely increase public confidence, would stand a better chance of satisfying the National Environmental Policy Act and meeting regulatory requirements, and, all things being equal, would improve odds of obtaining a technical success. The case-by-case approach, in contrast, held the advantage of reducing the time it might take to develop an operating facility. That approach would also lessen logistical difficulties that might arise in transporting waste from storage, and entail lower near-term costs.

However, after the first draft of this analysis was circulated within IRG and after informal discussions between staff members of DOE and OSTP, agreement was reached to remove the case-by-case strategy from further consideration. Without any fanfare, then, and for reasons which are still something of a mystery, DOE abandoned its traditional decision principle for repository siting, one which it had reaffirmed only 4 months previously.

The sole remaining issue with respect to siting strategy was how many sites in what geologic environments would be used in the comparison. DOE argued for two or three while most of the rest of the IRG agencies called for four or five. The relatively small difference in number disguised a large difference in substance. For the question was whether the waste management requirements could be satisfied by the existing program or whether an expanded effort of geologic investigations would be required prior to the selection of the first repository site. This conflict was ultimately resolved by the President in favor of the more redundant strategy.[96] NRC, in 1981, developed its own procedures that mandated some degree of intercomparison before a site is presented for regulatory review and licensing.[97] In particular, NRC required that three sites in at least two different media be evaluated before a permission will be given to begin repository construction.

Developing a Waste Package

High-level waste streams from a reprocessing plant and, to a lesser extent, spent reactor fuel can be transformed into different waste forms prior to their disposal. The potential variety of form is wide, ranging from essentially untransformed materials to waste forms carefully designed to be compatible, and perhaps in thermoequilibrium, with repository rock. In addition, the waste form itself may be surrounded by other material to protect it further after emplacement in, for example, a geologic repository. The waste form and accompanying material surrounding the waste are termed a waste package.

The state of the art of materials science determines the range of feasible alternatives of waste form and packaging. But there are several issues that must be addressed before the final choice is made. To what degree is there confidence that the geology of a repository will perform its job reliably to reduce demands on the waste form? What economic costs are justified to obtain certain levels of reduction in the long-term ***risk?*** What improvements are needed in the waste handling and transportation process itself? How are long-term advantages and disadvantages balanced against short-term ones? In this section, we shall analyze how those issues were addressed, implicitly and explicitly, as the idea of an ‘ ‘acceptable’ waste form evolved.

As early as 1957, the AEC staff reported that work was under way to “concentrate and fix the radioactive waste material . . . in a stable, solid medium so that migration of the radioactivity into the environment is eliminated or reduced to safe limits. ’[98] Among the approaches investigated were conversion to oxide by heating (calcinating), self-sintering with natural earth materials, and fixation of the waste in synthetic feldspars, clays, ceramics, and glasses. Nine years later, research on waste forms had advanced to the point where the NAS Radioactive Waste Committee could observe that it was “favorably impressed with the whole solidification program’ and that it was “especially hopeful about glass or ceramic products, because they may be safe from serious leaching and, thus from release of hazardous radionuclides, for periods of centuries. ’[99]

Despite the promise of waste from research, waste management practices proceeded along a largely inde-

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[95] Confidential interview with author, 1978.

[96] See announcement of waste management policy by President Carter, Feb. 12, 1980.

[97] *Federal Register* 46, Feb. 25, 1981, p. 13979.

[98] Atomic Energy Commission 180/6, *op. cit.*, p. 28.

‘National Academy of Sciences/National Research Council, *Report to the Division of Reactor Development and Technology, U.S. Atomic Energy Commission, 1966,* p. *28.*

pendent track throughout this period. An examination of decisionmaking prior to 1970 at the major centers of waste storage/disposal—West Valley, Savannah River, Hanford, and Idaho—illustrates that point.

The promise of a waste form that would contribute to safety was ignored most blatantly at the NFS reprocessing plant at West Valley, N.Y. There to the extent that storage of liquid waste in tanks would become the means of disposal—and that appeared to be the most likely outcome at the time—the waste form became the neutralized stream from the extraction process. Implicitly, NFS, AEC, and the State of New York made the judgment that the economic and health costs and the technological uncertainties involved with more sophisticated waste forms overwhelmed any short-term advantages of waste processing. Obviously, such an assessment had as its premise the view that perpetual institutional control of the waste provided as much protection for the public health and safety as other options such as geologic storage.[100] The historical record is unambiguous that NFS, prior to 1970, did not devote any significant effort to designing or developing the alternative waste forms that might be necessary should the strategy of perpetual institutional care be abandoned.

In many respects, the consideration of waste form at Savannah River was also superficial because of the presumed mode of disposal. Beginning in the late 1950's, proposals were advanced to inject the facility's waste into the dense, crystalline bedrock underlying the site. AEC production division staff believed that three geological barriers would provide independent obstacles to the movement of the mobile waste in slurry form: the crystalline bedrock itself; the saprolite clay overlying the rock; and the aquifer overlying the clay. Alternative waste forms and disposal options were almost totally ignored.[101] This position was taken largely because the production division staff and that of its Savannah River contractor, the Du Pent Corp., believed that:

> Cost estimates indicate the solidification and off-site shipment of the waste . . . would be an order of magnitude greater than **placing the waste in bedrock caverns. Furthermore, the hazards involved in processing and shipping this large volume of highly radioactive material might be avoided.**[102]

The geology of the Hanford site did not permit a scheme analogous to bedrock disposal. Therefore, other disposal options were considered. This led, in turn, to a somewhat more intensive examination of waste forms. The production division staf and the personnel of Hanford's contractors, Atlantic Richfield Corp., were predisposed to a disposal technique premised on near surface burial of waste in engineered structures. Such an option could easily and inexpensively accommodate the large volumes of waste as well as the fact that a substantial fraction of the liquid waste had been reduced to salt cake to prevent loss of material in case of a leak. Using the near surface burial technique also meant that a waste form only had to be developed for the residual liquor. That could be expediently converted to an aluminosilicate material-a sort of "cement." Those involved in the Hanford operations did recognize, however, that the near-surface disposal option might not provide the long-term safety margins deemed acceptable. Thus, the possibility of solidifying the waste—perhaps using the spray calcinator developed at Richland—prefatory to onsite or offsite geologic disposal was acknowledged.[103] Yet, as in the case of Savannah River, concern was expressed that under such an alternative "costs would be increased.[104]

The only instance where waste management planning and waste form research merged was at the National Reactor Test Station in Idaho. Two factors accounted for this exception. First, geologic and hydrologic conditions militated against final disposal at the site. Second, because only relatively small volumes of waste were involved, it was possible to use stainless steel tanks from the start to store the liquid waste. This, in turn, allowed the operators to avoid neutralizing the waste with large quantities of base. These two differences created at once a need, an incentive, and a favorable technological circumstance for developing a more elaborate waste form. By the end of the 1960's, the Waste Calcining Facility was converting 400,000 gal of waste per year into a granular solid.[105] The solid could be stabilized by heating to 900° C. But even so, it possessed a high leach rate for both strontium and cesium,[106] This waste form, however, would facilitate material handling and transportation at a relatively small economic cost and health hazard. Yet, the form itself, like its more primitive cousins at Savannah River and Hanford, would only contribute marginally to the long-term containment of the waste.

As the 1970's began, then, policymaking on waste form was almost totally subordinated to the more general question of disposal option. Because each of the four waste centers took different stances on the basic issue, it was not surprising that they held divergent views on the secondary one. This pluralism of approach, while perhaps justifiable in a strict technical sense, did lend an ad hoc air to policymaking that made the program susceptible to public criticism. To forestall this and to

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[100] See the discussion in *Chemical Repressing plants.*

[101] General Accounting Office, *Observations Concerning the Management of High Level Radioactive Waste Material,* Washington, D. C., 1968, p. 27.

[102] "NAS Review of SR Bedrock Caverns Concept, " SECY-148, July 28, 1970, p. 2.

[103] *Plan for th. Management of AEC* Radioactive *Waste,* WASH-1202, U.S. Atomic Energy Commission, Washington, D. C., 1972, pp. 13-16.

[104] Atomic Energy Commission 180/30, op. cit., p. 6.

[105] *Plan for the Management,* op. cit., p. 20.

[106] *Alternatives for Managing Wastes,* op. cit., pp. 6.16-6.21.

impose some order on at least a portion of the waste production sites— the new commercial reprocessing plants to be constructed—AEC moved to promulgate appendix F to 10 CFR 50.[107] AEC resolution of the disposal issue for the private sector led, virtually automatically, to greater closure on the waste form question.[108]

As noted above, appendix F, the first formal regulatory policy statement for commercial high-level waste disposal, committed the Federal Government to build and operate a geologic repository. Implicit in that commitment was the judgment that such a technical means was the soundest option in terms of the long-range public health and safety. Such a judgment, although not based on any extensive risk analysis, foreclosed the perpetual care alternative used by NFS. It also cast a shadow over the bedrock approach and to a lesser extent Hanford's near surface burial scheme.[109]

Appendix F also resolved, again sometimes implicitly, some corollary issues. There would only be a few repositories built—one would serve the industry's needs up to 2000. Thus, waste would have to be transported to the central repository over long distances from the commercial reprocessing plants which were in various stages of operation and construction. Because transportation of millions of gallons of highly radioactive liquid waste was deemed too hazardous, waste solidification would have to take place at the reprocessing facility.[110]

AEC still had to fill in some critical details: When would conversion to a solid waste form occur? What would be the chemical composition of that solid waste form? Initially, the AEC staff suggested that both those issues be finessed, postponed until some other time. One paper AEC considered called only for conversion prior to the "retirement of the reprocessing facility from operational status, and only for "an AEC-approved solid form.[111] Commissioner Ramey instigated changes which ultimately led to the requirement that the liquid waste be converted within 5 years after their production.[112] Comments from the nuclear industry about the ambiguity surrounding the term "AEC-approved' prompted a clarification which specified that the solid had to be dry as well as chemically, thermally, and radiolytically stable. That clarification hardly defined the solid form unambiguously. Yet, when Chairman Seaborg asked whether more detailed volubility requirements might be included, the Director of Regulation responded:

> A major advantage of the salt disposal concept is that the material has been dry for millions of years, thereby eliminating the importance of volubility considerations. Furthermore, the small but finite volubility of even the most insoluble waste solids developed to date did not provide any additional protection over that provided by the integrity of the salt formation.[113]

Many have applauded the adoption of appendix F as a sound public policy decision. It limited the number of disposal sites and foreclosed the obsolete and hazardous option of disposing liquid waste. But it is critical to recognize the limitations of the appendix's scope. It would never affect the operations at Savannah River or at Hanford, and it did not affect the waste which had heretofore been produced at West Valley. At those sites the same waste management plans, which discounted the potential virtues of waste form, could be implemented. Even for new commercial reprocessing plants, waste form was not viewed as something to pursue for anything other than short-term advantages.

The comments of the Director of Regulation suggest the view of many AEC staff members at the time—the issue of waste form had largely been resolved by appendix F. After all, the Idaho facility had been producing calcined waste for nearly a decade; General Electric had adopted this same process for its proposed reprocessing plant at Morris, Ill. This view seemed so entrenched that, when Milton Shaw, the author of appendix F, severely cut back funds for waste form research at Hanford to save money for the breeder development program, strong objections from the head of AEC's Operational Safety Division were ignored,

This presumed closure on the waste form issue lasted only a few years. Commissioner Larson, an underwater explorer who had seen glass siting undecomposed on the seabed, began to argue that developing ' 'an essentially insoluble solid form for our radioactive high-level waste . . . should be one of the highest priority efforts in our waste management program. Those arguments resonated as it became increasingly clear that the unstated assumption of appendix F, early establishment of a repository, would not be fulfilled. In fact, by 1974, AEC'S waste management policy was premised on extended surface storage in the RSSF. The shift in policy direction had to be coupled, AEC'S Waste Management Director asserted, with a shift in policy regarding waste form:

> The probability of failure of the RSSF is proportional to the time in storage, and protection against the conse-

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[107] 'Siting of Commercial Reprocessing Plants and Related Waste Management Facilities, AEC 180/47, Oct. 9, 1968.

[108] Siting of Commercial Fuel Reprocessing Plants and Related Waste Management Facilities, " SECY-160, July 31, 1970.

[109] Siting of Commercial Fuel Reprocessing Plants and Related Waste Management Facilities, " AEC 180/88, June 17, 1970, p. 29.

[110] App. F required that the liquid waste be converted to a solid form within 5 years after reprocessing and the solid transported to a Federal repository no later than 5 years thereafter. The timing was somewhat arbitrary but represented a balance between waiting for the waste to cool and avoiding large build-ups of liquid waste.

[111] Atomic Energy Commission 180/47, op. cit., p. 5.

[112] Memorandum, Thompson to the other Commissioners, June 22, 1970, p. 3.

[113] Minutes of Commission Meeting 2429, Aug. 8, 1970, pp. 10-11.

[114] Memorandum, Larson to the other Commissioners, June 26, 1972.

> quence of escape during extended surface storage would be enhanced by modifying the waste to a form having a lower probability of dispersal to air (by decreasing the surface to volume ratio) or to water (by decreasing leachability). The probability of dispersion can be decreased by having the waste in a massive low-leachable glass (or ceramic) form while it is in surface storage. [115]

It was recognized that a change in position on the waste form question could have unsettling effects on the emerging reprocessing industry. Thus, the waste management staff recommended that a centralized glassmaking plant be built at the RSSF site by AEC. [116]

Significantly, in neither the public nor internal record is there any consideration of the desirability of the glass waste form in terms of long-range, hundreds of years, safety. Nevertheless, the demise of the RSSF and the proposed Calcine Conversion Facility and a return to an emphasis on geologic disposal did not mark the end of the glass waste form. Only 5 years after it was dismissed by the Director of Regulation, it came to figure prominently in the center of the "Baranowski bull' s-eye' which graphically depicted the multiple barrier design or repositories. Waste form, presumably glass, was seen, for the first time, as something more than a modality for moving waste; it had become a means of significantly improving repository performance. [117]

Once waste form was certified as an important potential contributor to long-term safety, it took little time before the choice of glass came under attack. By 1976, borosilicate glass was already being criticized for having too high of a leach rate and for being too subject to devitrification. [118]Within the materials science community, the debate over waste form raged furiously and eventually ignited into controversy over an NAS report on the subject. [119]Behind the technical substance of that debate, however, is a more fundamental policy question: to what degree should waste form and packaging be elevated from the potential contributor to long-term safety to a fully redundant element of a waste management system?

Currently, the staff of DOE maintains that borosilicate glass, while perhaps not the ultimate waste form, is good enough. They believe that other forms would be costly and time-consuming and potentially more hazardous to develop. Those disadvantages would not be outweighed by large gains in long-term system reliability because the geology of a repository can be depended on. The staff of NRC argues that "it would be highly desirable to place major, if not primary, importance on the waste form itself, its packaging, and the local waste-rock interface. This would leave the geology as a fully redundant additional barrier. [120] The regulators' position clearly derives from a more skeptical view of the potential for predicting the behavior of repository systems and geologic formations far into the future. One indicator of the intensity of the NRC position is the fact that in its proposed technical criteria for regulating geologic disposal of high-level radioactive waste only one specific standard is set forth: the performance criteria for the waste package.[121]

Determining Acceptable Safety Levels for a Geologic Repository

In the previous two sections, the discussion has focused on strategies for finding "acceptable' sites for a repository and on the desiderata for an ' 'acceptable' waste form package. We have not considered the process through which acceptable levels of safety are determined and precisely what those levels are. This section will consider how the process of determining what is acceptably safe has evolved over the last 12 years. However, because the process has not yet reached closure, no statement can be made about its outcome. Instead, this section will also explore the implications of developing sites and waste packages absent a final determination of acceptability.

Judgments about acceptability, it must be recognized, are fundamentally matters of preference. Scientific and technical findings can inform those judgments by clarifying what the levels of safety associated with particular system design or repository siting decisions are likely to be. Even if those findings should be consensually accepted as being empirically accurate (no small task in itsel~, it still remains for the individual or society as a whole to determine, based on a set of values, whether those levels of safety are satisfactory or not. [122] In the final analysis, then, judgments about acceptability cannot be validated or invalidated; they have the same status as questions of taste.

Prior to 1975, no formal process had been set into place to resolve explicitly the issue of acceptable levels of safety. To be sure, an AEC licensing board during the 1960's did grant construction and operating permits to the NFS reprocessing plant at West Valley, N.Y. [123] Implicit in those authorizations was the judgment that

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[115] "Pros and Cons of Alternative Roles of Government and Industry Reconverting High-Level Waste to Glass, " SECY-74-673, May 28, 1974, p. 1.

[116] Ibid., pp. I-2; see also WASH-1539, pp. 2.5-31—2.5-34.

[117] No record can be found pertaining to the origins of this elevation of waste form.

[118] This criticism was first raised in 1976 and was incorporated into the American Physical Society study, op. cit., pp. *S128-S132*.

[119] See Luther Carter, "Academy Squabbles Over Radwaste Rep-t," *Science* 205, July 20, 1979, pp. 287-289.

[120] Letter, Jack Martin to Sheldon Meyers, June 11, 1979.

[121] *Federal* Register, March 1981.

[122] See *Report* to *the President*, Interagency Review Group on Nuclear Waste Management, TID-29442, Washington, D. C., March 1979, p. 42.

[123] A provisional construction permit—CSF-1—was granted Nuclear Fuel Service on Apr. 30, 1963.

the storage of liquid waste in tanks for an indefinite period of time posed an acceptable burden to society. But, pragmatically, the drive to introduce commercial reprocessing totally dominated considerations of the appropriate level of acceptability for managing the waste generated by the facility.

The repository proposed for Lyons, Kans., in 1970 provided another instance where a judgment had to be rendered about the site and repository design's acceptability. Because AEC ultimately chose to abandon those plans, no definitive assessment of acceptability was ever made. Nevertheless, the environmental impact statement for the project documents well the logic of how such decisions were made at the time. [124]

Two features of that logic are particularly striking. First, the process for determining the acceptability of a site and repository design was illustrated. Views about what constituted an acceptable social burden were admitted from only a narrowly based segment of the policy. In particular, the value judgment offered by the NAS'S Committee on Radioactive Waste Management that "the use of bedded salt for the disposal of radioactive waste is satisfactory" was endorsed and accepted. [125] The views of elected officials in Kansas that the specific project was too risky were discounted. [126] This situation is somewhat ironic because, only 4 years previously, AEC ignored the value judgment of a majority of the NAS Committee that the Savannah River bedrock project was unacceptably hazardous and proceeded with site exploration, [127] second, because no a priori standards for site suitability were ever explicitly enunciated, even this narrowly based judgment of acceptability could not be held accountable. Selection of a site in the absence of explicit standards for acceptability raised concern in some quarters that AEC would be able to shoot an arrow at a wall, to draw the target around where the arrow landed, and then to pronounce itself an expert marksman.

With the withdrawal of the Lyons EIS in 1972, and with AEC falling back to a strategy of long-term surface storage, a hiatus of activity emerged and, as a result, an opportunity arose to adjust the process by which matters of acceptability might be resolved. No evidence is available which suggests that such an effort was undertaken. The prevailing view within the AEC during that 1972-75 period appears to be that, whenever the time came to develop a repository, judgments about acceptability of a site and a design would be rendered in much that same relatively closed and informal fashion as they had been in the past.

Starting in 1974, however, the process for determining acceptability in waste management began to undergo two fundamental alterations. First, EPA, after years of bureaucratic in-fighting, established a firm toehold in the domain of radiation protection standards. EPA issued standards for the front-end of the nuclear fuel cycle, for reactor operations, and for reprocessing of spent nuclear fuel. [128] In addition, the agency announced it intended to develop standards for the disposal of nuclear waste. Such criteria would, for the first time, impose explicit constraints on repository developments.

The second change was the passage of the Energy Reorganization Act of 1974. That law, which took effect in January 1975, abolished AEC and established in its place ERDA and NRC. The motive behind the legislation's approval was to remove a potential-many believed actual-organizational conflict of interest by separating the development of nuclear power from its regulation. Not surprisingly, then, both the House and Senate bills contained language authorizing NRC to license any "facility used primarily for the receipt and storage [sic] of high-level radioactive wastes. [129] The notion of an independent review of a repository project was one of those proverbial ideas whose time had come. A review of the legislative history of the ***Energy*** Reorganization Act finds no record of opposition to this provision—one which represented a major policy shift.

The entry of EPA and the establishment of independent review authority for NRC marked the transition from an informal process of determining acceptability to a formal process of regulation. First ERDA and then DOE would have to choose a site and design a disposal facility that would meet the regulations that NRC promulgated to ensure that EPA's standards would be satisfied. What was and still is indeterminate was how the regulatory role would evolve and mature.

Conceivably, there are a spectrum of approaches under which the regulators might interact with repository developers. At one extreme, the regulators adopt a relatively passive posture. The developers proceed with their efforts absent any regulatory guidance under the implicit assumption that any facility constructed would ultimately have to be accepted by the regulators. Under this approach, regulation would ultimately degenerate into a posteriori approval. At the other extreme, the regulators would establish criteria and standards independently of the developers and compel those responsible for repository siting and design to

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[124] Lyons' Environmental Impact Statement, pp. 8-13.

[125] National Academy of Sciences/National Research Council, Disposal *of Solid Radioactive Wastes in Bedded Salt Deposits, 1970,* p. 1.

[126] See Lyons' Environmental Impact Statement, pp. 55-5105.

[127] National Academ, of Sciences/National Research Council, 1966, pp. 7'3-75.

[128] See, En *vironmental Analysis of the Uranium Fuel Cycle,* EPA-520/9- *73 003,* Environmental Protection Agency, Washington, D. C., 1973; and 40 Code *of Federal Regulations 190,*

[129] Energy *Reorganization* Act of 1976, sec. 202(3).

conform. The developers could proceed only with generic studies until final regulations were promulgated. Mixed approaches might also be adopted. For example, regulation and development could emerge as interactive, iterative, and somewhat informal activities. The developers provide information to the regulators about what is technically possible. Moreover, the developers disregard technical possibilities that seem unlikely to be viewed positively by the regulators. At the same time, the developers pursue designs that allow key parameters to be modified within a range that is likely to include the regulatory standard. Thus, the regulators and the developers work together through the site selection process and up to the time licensing commences.

Settling on a regulatory approach is no easy matter. The first alternative, while the least time-consuming, is almost certainly legally tainted; moreover, political opposition to it would be vocal and intense. The polar extreme, however, is just as problematic. EPA has still to issue its standards, even in draft form. Without those standards, NRC job of issuing detailed regulations becomes more complicated. In short, if the developers were simply to wait for the regulators to act, substantial unfortunate delays would well result. What is clear today, that neither extreme approach is viable, was sensed back in 1975. Some mixed approach had to be taken. How that course was charted and its implications are the subjects to which we now turn.

All mixed approaches, by definition, entail interaction between the regulators and the developers. What distinguishes one such approach from another, however, is which of the two sides provides the driving force that shapes their relationship and how strong that thrust is. When NRC was first created, it possessed neither the institutional knowledge nor the resources to deal with ERDA on an equal basis. As a result, NRC's regulatory efforts were initially designed to track ERDA's developmental plans. As those plans shifted, however, NRC found itself in the position of having to recast its own priorities. For instance, NRC first concentrated on developing procedures and techniques for regulating the choice of site and designing of repositories in bedded salt. When a domed salt facility became a leading contender, NRC found that it could not develop new regulatory tools in time to meet the deadlines then envisioned.

As NRC matured as an institution, the balance between the regulators and the developers (now DOE), shifted, resulting in changes in the character of the prevailing mixed approach. The publication of NRC's policy statement on licensing procedures for geologic repositories marks one stage in that evolution. [130] The proposed policy called for informal regulatory review of the developers' site selection decision. The NRC staff might provide comments and advice but the Commission itself would not make any formal findings or take any formal action. The developers would be at liberty to proceed as they chose in the face of that guidance. The first formal DOE-NRC interaction would occur prior to the sinking of the repository shaft. NRC could either authorize repository construction if certain findings were made, or it could delay authorization until additional data was obtained from sinking the shaft. Unresolved safety issues might be deferred until construction was completed if it was felt that further research was likely to yield favorable solutions. A second formal licensing review would occur prior to the receipt of radioactive material at the repository. NRC concurrence would also be required at the time of closure and decommissioning.

Implicit in those proposed procedures was a vision of the relationship between regulator and developer. In particular, the NRC staff believed that it was essential for the regulators to intervene formally in the process before substantial organizational and resource commitments to the site had been made by DOE. Absent such early involvement, the regulators faced a risk of being swept along by the developers' momentum. Herein, then, lay NRC's first major effort to assert the initiative in its relations with DOE.

Yet, almost as soon as the proposed policy statement had been issued, the NRC waste management staff, now under new leadership, began to question the policy's logical foundations. [131] In particular, the staff came to believe that any formal authorization prior to the sinking of the shaft, or even after it for that matter, would have to be made on the basis of incomplete and inadequate data. For emerging scientific opinion, articulated by the USGS, NAS, and the President's Interagency Review Group, suggested that "exploration and testing at depth should be performed to determine whether the surrounding geology will retard waste migration. [132] Thus, NRC proposed to require such investigations prior to issuing a permit for constructing a repository.

This shift increased the risk of premature commitment and the concomitant pressures such a commitment might generate. Recognizing that NRC might lose the initiative in dealing with DOE, the revised procedural regulations adopted new strategy: "To guard against DOE's making a premature and preemptive commitment to a particular site in a particular medium . . . this [revised] approach provides for characterization of a number of sites at different locations and in different

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[130] *Federal Register 43, Nov. 17, 1978, pp. 53869-53872.*

[131] *Federal Register 44, Dec. 6, 1979, pp. 70408-70421.*

[132] Ibid., p. 70410.

media[133] Thus, a multiple-site strategy not onlY emerges as the one seemingly most consistent with the realities of geologic understanding, but it is also an effective means of asserting regulatory control over the actions of the developers.

The evolving shift in the force driving the relationship between the regulator and the developer can also be observed in the proposed technical criteria issued by NRC in 1981.[134] Three examples stand out as being particularly striking in this regard. The first is the requirement that the waste package contain radionuclides completely for 1,000 years. The second is the extensive discussion given to the problem of human intrusion. The third is the clear signal that alternative waste forms and packages be investigated. None of these requirements appear to be at all arbitrary or constitute an abuse of regulatory discretion. Yet each could also reasonably be interpreted as a technical maneuver designed to force DOE to retrofit its program to conform with the regulator's desires. Certainly part of DOE's negative reaction to the 1,OOO-year waste form requirement could be viewed in this light. Moreover, NRC strong concern about the issue of human intrusion has ***to be*** understood in the context of the controversy over the Waste Isolation Pilot Plant site. In that instance, DOE appeared ready to proceed despite the presence of amounts of potash in the area that might prompt exploration and exploitation in the future. Finally, the dictum about alternative waste forms and packages must be read in the light of the criticism NRC has made about the adequacy of the DOE program.

The developmental program has continued to expand even as the relationship between NRC and DOE evolved. And not unexpectedly some costs have been paid because of this. Perhaps the most significant one has occurred in the realm of site selection. Absent formal regulatory guidance, DOE has had to develop its own selection criteria. Although they have made a serious effort to accomplish that task responsibly,[135] it does seem clear that resource and organizational commitments have been made to sites that might not conform to NRC's selection criteria or satisfy NRC's procedural requirements for choosing sites for characterization. In the view of some observers the process for selecting the sites is flawed and further work on them merely undermines public confidence in the program.[136]

The Relationship Between the Federal Government and the States in Nuclear Waste Management

The Federal Government and several States can possess overlapping jurisdictions and share powers. In the field of nuclear waste management, the Federal Government through NRC has entered into agreements with a number of States whereby the latter entities regulate the activities of low-level waste burial grounds.[137] Current law specifies that the States take over this responsibility fully through the formation of regional compacts.[138] In the domain of high-level waste **disposal,** however, Federal law, at least at this time, * does not authorize and probably precludes the sharing of power and authority. Nevertheless, successful implementation of a high-level disposal plan requires that the States be intimately involved. For behind a formal lack of State power lies a plethora of informal powers that must be accommodated. The accommodation is necessary because the States firmly believe that they must protect the unique interests of those residing within their jurisdiction.

In this section, we shall examine how Federal officials responsible for waste management began by discounting the informal authority of the States, believing that it would not be exercised, and ended up conceding to the States formal powers that legally could not be rendered.

AEC'S involvement with the States dates back to the earliest days of the waste management program. At that time, AEC worked closely with local health officials and sanitary engineers in the design of facilities to store waste from the military program. By 1956, AEC was consulting with State and interstate public health and water pollution control agencies and was involving State governments in the evaluation of geological and hydrological problems associated with disposal of liquid and solid waste. Moreover, a continuing dialog was reported to be taking place on the waste management issue through such mechanisms as AEC'S Advisory Committee of State Officials and the Council of State Governments. One analysis for AEC observed that this Federal/State interaction had been quite positive and recommended that it be continued and strengthened. Yet, the analysis concluded, that relationship could prosper only if it "rested on information derived from sound research and development programs integrated with knowledge and

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[133] "Proposed New 10 CFR Part 60—Disposal of High Level Radioactive Wastes in Geologic Repositories—Procedural Aspects, " SECY-79-580, Oct. 22, 1979, p. 6.

[134] *Federal* Register, March ~981.

[135] See, NWTS *Criteria for the Disposal of Nuclear Wastes: Site Qualification Criteria*, ONWI-33(2) (Columbus, Ohio: Battelle, 1980).

[136] See some of the critical *comments on* the siting choice and the Department of Energy's response to them in *Final WIPP EIS,* DOE/EIS-0026, *1980.*

[137] Agreement States authority is found in the Atomic Energy Act of 1954, as amended, sec. 274.

[138] See Low Level Waste Management Policy Act of 1980, which passed Congress on Dec. 13, 1980.

* Prior to passage of the Nuclear Waste Policy Act of 1982.

appreciation of the experiences of . . . communities in resolving their . . . environmental problems. [139]

Over the next decade and a half, the character of the Federal/State relationship did not significantly change. Then, as noted above, in 1969, a fire broke out at AEC'S military facility at Rocky Flats, Colo. Considerable quantities of plutonium-contaminated debris were produced. The material was shipped to the waste storage grounds at the National Reactor Test Station (NRTS) in Idaho. Concerned about NRTS'S role as a "dumping ground, " Idaho Senator Frank Church requested a multiagency investigation of the facility's operations and environmental impacts.[140] Although the subsequent report clearly indicated that AEC'S practices in Idaho fully protected the health and safety of the State's population,[141] Church, backed by Governor Cecil Andrus, pressed for a commitment from AEC to remove the wastes and dispose of them elsewhere. 142

AEC recognized that such an action was consistent with its evolving waste management policy. Even before the Rocky Flats fire, AEC had moved toward an approach for commercially generated waste that centered on the use of Government-owned repositories. It was certainly feasible to use those planned facilities to dispose of the transuranic contaminated waste stored at Idaho. Thus, AEC Chairman Seaborg agreed to honor Church's request and promised to begin removing the waste by 1980.143 That commitment marked the first time a State had substantively affected the direction of AEC policy. The States' role had clearly expanded beyond providing technical collaboration.

It is ironic that AEC'S sensitivity to—or at least a pragmatic recognition of—the concerns of the States in the case of Idaho directly influenced its decision to undertake the Lyons project, an endeavor which since has come to be viewed as so lacking both in sensitivity and pragmatism with regard to the State of Kansas. [144] Earlier in this paper the technical issues that cast a shadow over the project's viability were noted. It is important to recognize that as the exploration and characterization of the site progressed, the political atmosphere was quite turbulent as well.

In the decision memorandum the Commissioners approved authorizing the Lyons project, explicit directions were given to the staff to "consult with State officials. [145] The written historical record is unclear about the scope of those consultations. Nonetheless, it is likely that members of the Kansas Geological Survey and probably the staff of the Governor's office and of local legislators were briefed. What we do know is that no unambiguous commitments of political support for the project by the State emerged from those consultations. AEC had not "lined up its ducks" at the time of the public announcement on June 17, 1970, that Lyons had been tentatively selected as the first repository site, [146]

AEC'S politically exposed position made it more vulnerable to first the skepticism and then the criticism of U.S. Congressman Joseph Skubitz, who represented a Kansas district which did not include Lyons. Skubitz began by asking a straightforward question: why had the Kansas salt fields been selected rather than a site in the Salina basin that would have been closer to the operating and planned reprocessing plants in New York, Illinois, and South Carolina? The agency responded by saying the Kansas site possessed "geologic characteristics . . . generally more favorable than those of the salt in the Salina basin. " AEC furthermore justified the long transport routes to Kansas by postulating a reprocessing plant in California; that hypothetical plant would then make Lyons a centrally located spot.[147]

AEC'S answer to Skubitz was misleading in that it emphasized the technical bases for the choice and virtually ignored the nontechnical factors. [146] The site selection process, as we noted above, was less than systematic; the analysis supporting the choice of Lyons took up less than eight pages. Yet, even the analysis concluded that Lyons enjoyed, at best, only a marginal technical advantage over other potential sites. If anything, the Kansas salt mine was chosen because of local acceptance of the experimental Project Salt Vault and because AEC did not want to wait for—nor did it have the resources to fund—an investigation of other locations.[149] All this is not to say that AEC'S choice was wrong; simply it was less than candid in dealing with one Representative from Kansas.

AEC also had difficulty in answering specific technical questions raised by Skubitz with the obvious help of Kansas Geological Survey's new director, William Hambleton. Concerns were raised about the thermal effects of the geological system, about the problem of brine inclusion, about the available techniques for borehole plugging, about possible mechanisms for retrieving the waste if necessary, and about the potential for radiation damage to the salt. Many of these same concerns were held by AEC and NAS, But because AEC had only skimpily funded waste management research and development, very few definitive studies could be cited to bolster the agency's claim that the site was sound.

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[139] Atomic Energy Commission 180/5, op. cit., p. 14.

[140] Letter, Church to Seaborg, Sept. 13, 1969.

[141] Letter, Bureau of Radiological Health to Church, February 1970.

[142] Letter, Church to Seaborg, Apr. 30, 1970.

[143] Letter, Seaborg to Church, June 9, 1970.

[144] For an example of such a view, see H. Peter Metzger, *The Atomic Establishment* (New York: Simon & Schuster, 1972), pp. 154-160.

[145] Atomic Energy Commission 180/87, op. cit., p. 6.

[146] Atomic Energy Commission Press Release, N-102, June 17, 1970.

1* 7Letter, Erelwine to Skubitz, June 11, 1970.

[148] Atomic Energy Commission 180/87, op. cit., pp. 4, 16.

[149] Atomic Energy Commission *180/81*, op. cit., pp. 4-6.

Instead, AEC pointed to work under way to resolve many of those issues and, in essence, sought to hold the debate in abeyance until the research reached fruition. Skubitz, however, strongly argued that it was inappropriate to select a site, even tentatively, absent those technical findings. For him, AEC's decision to proceed with work at Lyons was both a premature commitment and an act of faith, a faith he did not share.

In the months after the project was publicly announced Skubitz was in the forefront of the attack. Other Kansas officials seemed to adopt a wait-and-see attitude. That was not to last for long. Spurred on by AEC's seeming lack of candor, disturbed by the agency's underdeveloped technical program, and irritated by what they saw as AEC's patronizing and arrogant manner, other local officials soon joined the fray. By the beginning of 1971, Governor Robert Docking had become a firm opponent of the Lyons project, and began to question AEC'sw motives and good faith.[150] Eventually, in August 1971, both of Kansas' Senators, Robert Dole and James Pearson, sponsored an amendment to AEC's authorizing legislation prohibiting buying of land or burying waste materials at Lyons until such time as an independent advisory council, appointed by the President, reported to Congress that the establishment of a repository and burial of high-level waste could be carried out safely.[151] Thus, AEC's inability to satisfy the not altogether capricious concerns of State officials resulted in their losing considerable autonomy in implementing a major policy decision in waste management.

The Lyons experience had a profound effect on AEC and its successor agencies. While the RSSF was being planned, AEC engaged in intensive consultations with State officials from Nevada, Idaho, and Washington. And although State concerns were not completely resolved, intense confrontations never broke out as they did over the Kansas project.

By the time the RSSF was canceled and as ERDA reinvigorated efforts aimed at finding new sites for a geologic repository, nuclear energy policymakers clearly recognized that States had to become more intimately involved in waste management decisionmaking. Thus, in November 1976, ERDA's Administrator, Robert Seamans, wrote to State governors and legislators to inform them of the agency's plans to expand the site exploration program. The letter offered to work closely with the States and to keep the Governors informed of how the efforts were progressing. Most significantly, Seamans committed himself to terminating a project within a State "if the State raises issues . . . connected with [technical] criteria and their application that are not resolved through mutually accepted procedures.[152] The States, in effect, were being offered at least the potential of a veto over the construction of a waste facility within their jurisdiction.

The response of State officials was mixed. Some, such as those representing South Carolina, Kansas, Michigan, and Wisconsin, wrote to Seamans and explicitly disinvited ERDA from even exploring potential repository locations. Others, such as those representing New York, Missouri, and Colorado, were reluctant to welcome ERDA until further studies, such as the Generic Environmental Impact Statement on Waste Management, were completed. Finally, still others, such as those representing Oklahoma, Missouri, Mississippi, and Louisiana, did agree to work with ERDA to develop ground rules which might permit site exploration to proceed. No State, however, evinced much enthusiasm and one by one States soon were dropped from consideration. Thus, what began as a new initiative, a fresh start in the area of waste management, soon got mired down in the reluctance of State officials even to contemplate a facility on their soil.[153]

The expanded exploration program was directed at finding sites for disposing of commercially generated waste. A parallel effort to construct a repository in New Mexico for military waste had, as we noted above, been in progress since 1973. State officials and local influential had initially welcomed the possibility of utilizing a site near Los Medanos for a Waste Isolation Pilot Plant (WIPP).[154] By 1978, surface-level site characterization was well under way. And a correspondingly mature institutional relationship had evolved between the Federal and State Governments. The New Mexico Governor established a Radioactive Waste Consultation Task Force, an Environmental Evaluation Group, and an Advisory Committee on WIPP. Those groups carried out independent evaluations and assessed the technical validity of the characterization program and provided advice to the Governor. DOE funded a substantial fraction of that State effort.

Cooperation between the two levels of government was further facilitated by an informal agreement that provided the State of New Mexico with the right of concurrence on the construction of any facility proposed for the long-term permanent disposal of nuclear waste. The State interpreted that right to include the opportunity not to concur and on a number of occasions Federal officials acquiesced in that interpretation, Another factor which cemented the Federal/State partnership was the commitment from the Carter administration in 1978

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[150] See Letter, Dockings to Skubitz, Feb. 20, 1970, for first hints of Docking's growing opposition.

[151] See proviso inserted in AEC Authorizing Legislation for fiscal year 1972 for item 72-3-b, the proposed Lyons repository, op. cit.

[152] Letter, Seamans to State officials, Nov. 26, 1976, P. 3.

[153] *Report of Task Force*, op. cit., p. 12.

[154] Gourmley, op. cit., pp. 3-5.

that WIPP would be licensed by NRC.[155] Such an independent formal review process would help satisfy New Mexican concerns that the facility was indeed "safe."

By all accounts, then, as the 1970's drew to a close, DOE and New Mexican officials had established fundamentally strong working relations that were able to survive such occasional shocks as periodic shifts in the proclaimed functions WIPP would fulfill and disagreements over the adequacy of the draft WIPP impact statement. [156] In December 1979, however, Congress passed the Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980. That law was reluctantly approved by President Carter, who at the time of the signing expressed strong disagreement with the legislation's provisions affecting WIPP. In particular, the bill undermined the basis on which New Mexico's cooperation rested: it prohibited DOE from granting the State a veto over the construction of the facility and prevented its licensing by NRC.[157] Once again, DOE found its relations with a key State strained almost to the breaking point.

DOE's relationship with the States had developed in an ad hoc fashion over the last half of the 1970's. By early 1978, it became clear to many policy makers that that interaction had to be formalized and institutionalized. DOE began intensive consultations with the leadership of the National Governor's Association (NGA). NGA adopted a resolution in August 1978 which asserted that DOE had to "obtain State concurrence prior to final site determination. "[158] At precisely the same time, President Carter's Interagency Review Group on Nuclear Waste Management (IRG) was formulating the concept of 'consultation and concurrence. Under that approach, the "State would be in agreement with each step in the [repository development] process before the next activity' would begin. [159] The IRG formulation was ambiguous, perhaps purposely so. Six months later, IRG recast and clarified the concept. In particular, a distinction was made between consultation and concurrence and a State veto. The former, it was held, implied a continuing dialog between the States and the Federal Government; the latter suggested an action taken only at one discrete point in time. 'GO To many, IRG's distinction was without a difference: the obverse of concurrence was nonconcurrence, which was pragmatically equivalent to a State veto. Nevertheless, this formulation of consultation and concurrence made explicit a policy that had been informally pursued for several years; it also proffered more power to the States than they were, up to that time, legally entitled to.

The formalization by the executive branch of this policy raised two questions, neither of which has been definitively answered. The first question focused on the wisdom of granting the States the ability to delay or defer a critically needed national effort. Indeed, President Carter seemed to retreat from the recommendations of IRG when he emphasized the "consultation" phase and reemphasized the "concurrence" phase in his waste management policy statement.[161] Moreover, several Members of Congress expressed concern that DOE had gone too far in trying to satisfy the States' demands, thereby creating a dangerous precedent for the future. [162] Even some State executives indicated that they did not welcome the power not to concur. To have such authority, in their view, would virtually compel them to use it.

Yet, those who opposed endowing the States with substantive controlling influence over repository siting were probably in the minority. For the majority the real issue—and the second question raised by DOE's policy—was how would the modalities of the process be designed. In particular, what steps could the Federal Government take if it disagreed with a State's nonconcurrence? President Carter created by Executive order a State Planning Council (SPC) composed of Governors, legislators, and representatives of Indian tribes, to provide advice on issues such as that. [163] SPC resolved that, in case of disagreement between DOE and a host State, the latter could only be overridden by an explicit Presidential determination supported by both Houses of Congress. [164] When Congress itself took **Up** the issue in late 1980, both Houses agreed on an override mechanism for commercial high-level waste disposal: the host State would only be sustained if either the House or the Senate affirmatively concurred with the State's position.[165] Congress, however, could not agree on the right of a State to object to a facility designed to dispose of defense high-level waste. In fact, the disagreement was largely responsible for Congress' inability, at that time, to pass a bill dealing with high-level waste.

Linking Reactor Operation With the Development of Techniques for Radioactive Waste Disposal

> . . . the general problem of radioactive waste need not retard the future development of the nuclear energy industry with full protection of the public health and safety. [166]

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[155] Confidential interviews with author, 1978.

"'Ibid,, 1980.

[157] Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980, Sec. 213, 93 Stat. 1259.

[158] *Nuclear Energy Policy Position*, op. cit., adopted August 1978.

[159] *Report to the President*, TID-28817 (draft), Interagency Review Group on Nuclear Waste Management, Washington, D. C., p. 52.

[160] *Report to the President*, final report, op. cit., pp. 8896.

[161] Presidental Statement on Nuclear Waste Management Policy, Feb. 12, 1980.

[162] See, for instance, letter, Dingell to O'Leary, Apr. 21, 1978.

[163] Executive Order No. 12192, Feb. 12, 1980.

[164] State Planning Council Resolution No. 4-10.

[165] See, S.2189, sec. 908, 96th Cong. , for example.

[166] *Industrial Radioactive Waste Disposal*, op. cit., p. 3.

That statement gives expression to a particular logic. It holds that as long as a solution to radioactive waste disposal is clearly envisioned, there is no need to prevent the commercial nuclear industry from developing and maturing. Another logic can also be constructed. This one holds the generation of nuclear waste, particularly by the commercial nuclear industry, ought to be linked to a resolution of the problem of waste disposal. Which logic prevails depends strongly on the outcome of activities in the legal and political arenas. In this section, one will examine how those outcomes have made the linkage logic more salient although not dominant.

Throughout the period when AEC existed, Congress and the President implicitly sanctioned the development of a nuclear power industry unconstrained by the status of the waste management program. For a dozen years, 1959-71, one can find fewer than 25 pages of testimony about any aspect of radioactive waste management amongst the many thousands of pages reporting on hearings held by the JCAE on commercial nuclear power. [167] Two reports addressed to the President on civilian nuclear power mentioned the unresolved waste disposal question, but there is no evidence that President Kennedy, President Johnson, or their staffs saw in that unsettled issue any reason for concern. [168]Moreover, during that 1959-75 period, the nuclear industry contracted for all but six of the reactors ordered in this country. [169]Such a large financial commitment ensured that the industry's political clout would be used to oppose any action linking reactor deployment with progress in waste disposal.

AEC behaved in a fashion consistent with the incentives and signals provided by its political environment. The agency's policymakers and operating personnel rarely even entertained the idea that, as the waste management program lagged behind reactor development and deployment, the latter effort should be slowed until the former effort reached fruition. When they did consider the issue of linkage, it was always quickly dismissed. For example, a 1965 memorandum to Commissioner Ramey reaffirmed the validity of the conclusions adopted by the JCAE without offering any further analysis or rationale. [170]

By the early 1970's, however, AEC recognized that its political environment had changed somewhat. A memorandum prepared for an AEC policy session noted that "the uncertainties concerning location of the repository are already adversely affecting public acceptance of nuclear power, and it is possible that this aspect of the overall nuclear program could become an unnecessarily important negative factor in the Nation's ability to consider its nuclear option to power generation. [171] At about the same time, the agency also recognized that the National Environmental Policy Act required the consideration of the environmental effects of the uranium fuel cycle, including waste management, in reactor licensing hearings. [172] A year later, a staff **analysis** of waste management policies noted that any major changes in AEC programs "might be used by nuclear opponents as an indication that nuclear waste cannot be handled safely for the long term and that nuclear power should be halted. [173] But if perceptions of and demands from the political environment had begun to change, agency behavior did not. For example, AEC staff argued that the S-3 table, which quantified the environmental effects of the fuel cycle, need not even be considered because, "if factored into individual cost-benefit analyses, [it] would be sufficiently small as not to dect significantly the resultant conclusion. [174]When it came time to prepare the first programmatic environmental impact statement on commercial waste management, AEC did not analyze the option of shutting off reactors pending progress in the waste disposal program; to have addressed that option would have been in its view too time-consuming. [175]

The tenor of the political environment, however, shifted dramatically in 1976. In June, the State of California passed a bill which conditioned siting of reactors within the State on a finding that ' 'the United States through its authorized agency has proved that there exists a demonstrated technology or means for the disposal of high-level nuclear waste. "[176]When such a finding could not be made, a de facto moratorium on new nuclear reactors began in the State.[177]Although the law was overturned as an unwarranted intrusion in an area preempted by the Federal Government, [178]the fact that a powerful actor—the State of California—had firmly rejected the logic of JCAE was not lost. *

In a separate action, scarcely a month after the California Legislature had acted, the Court of Appeals for

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[167] See footnote 8 in *NRDC v.* Nuclear *Regulatory Commission,* 547 F.2d *633 (1976)* (Hereinafter NRDC v. NRC).

[168] See for example, *Civilian* Nuclear *Power—A Report to the President,* 1962, U.S. Atomic Energy Commission, Washington, DC., 1962. The brief section on waste management appears on pp. 54, 55.

[169] *The Nuclear Industry-1974,* WASH-11 74-74, U.S. Atomic Energy Commission, Washington, D. C., 1975, pp. 8-13.

[170] Pittman to Ramey, op. cit., p. 1.

[171] SECY-227 1, op. cit., p. 2.

[172] *Federal* Register 37, Nov. 15, 1972, pp. 24191-24193.

[173] "Policies for Management of Commercial High-Level Radioactive Waste, " SECY-74-222, Nov. 16, 1973, p. A18.

[174] *Federal Register, 1972,* p. 24192.

[175] *Nuclear Fuel Cycle,* ERDA-33, Energy Research and Development Administration, 1975, p. 47.

[176] California Public Resources Code 255 24.2, West Supp.1977.

[177] California Energy Resources Conservation and Development Commission, *In the Matter of Implementation of Nuclear Reprocessing and Waste Disposal* Statutes, No. 76-NL-1, 76-NL-3, Jan. 25, 1978, p. 5.

[178] *Pacific Legal* Foundation, et *al. v. State Energy Resources Conservation and Development Commission,* reported in CCH, Nuclear *Regulations Reports,* pp. 16, 621-16, 628.

● The law was ultimately upheld by the Supreme Court in 1983.

the District of Columbia invalidated the rule which was supported by the S-3 table. [179] Powerplant certification was abruptly halted and remained so for 2 months. More significantly, by holding that AEC had failed to develop the technical analysis for the rule adequately, the court became the first Federal institution to demand that a reasoned response and analysis of the consequences of waste disposal techniques be provided before additional reactors could be brought on-line: “Once a series of reactors is operating, it is too late to consider whether the wastes they generate should have been produced, no matter how costly and impractical reprocessing and waste disposal turn out to be; all that remain are engineering details to make the best of the situation which has been created. [160] In effect, the court’s opinion, while not mandating either logic, did reinforce the arguments of those seeking an explicit linkage between reactor operation and demonstrable techniques for waste disposal.

In November 1976, the environmental litigating group, the Natural Resources Defense Council (NRDC), petitioned NRC to conduct a rulemaking proceeding “to determine whether radioactive wastes generated in nuclear power reactors can subsequently be disposed of without undue risk to the public health and safety and to refrain from acting finally to grant pending or future requests for operating licenses until such time as this definitive finding of safety can be and is made. [181] By this petition, NRC was being asked to reconsider the logic that had guided Federal regulatory and developmental programs for 17 years. NRC denied the petition the following June. In the explanation of its denial, the Commission maintained that it was not obligated, under the Atomic Energy Act, to make the determination requested by NRDC. [182] That claim was later sustained in court.[183]

But in denying the petition, NRC did not reject the logic of linkage. It did state that “it would not continue to license reactors if it did not have reasonable confidence that the waste can and will in due course be disposed of safely. “[184] That statement advanced two critical policy innovations and was made at the insistence of the Chief of the Waste Management Branch over the objections of the Executive Legal Director. The first innovation was the distinction between “can and will. ” That distinction marked a departure from the posture of technological optimism. Second, the Commission’s explanation for its confidence was based on and tied to the general direction taken by both NRC and ERDA programs at that time. “The clear implication is that if the direction of the present program[s] should change significantly, NRC as a matter of sound policy may no longer be in a position to continue licensing reactors. [185]

The California laws, judicial review of the S-3 table, and the NRC response to the NRDC petition all left profound and depressing impressions on those defending the logic of the Joint Committee. Mustering their forces, those opposing linkage did prevail in the intense and bitter bureaucratic infighting over the Carter administration’s proposals for reforming reactor licensing procedures. Advocates of including a specific linkage provision found their views rejected by the President himself. The opponents of linkage were also heartened by the Deutch Report’s recommendation to dispose of 1,000 spent fuel rods at the WIPP, a recommendation many believe was prompted by a desire to satisfy California’s law.[186] Moreover, the President’s Interagency Review Group managed to avoid the question of linkage in preparing its analysis. [187] Yet despite these events, forces within the Government still pressed for a commitment to nuclear power which was dependent on progress in waste disposal. For example, one such advocate, J. Gustave Speth, formerly a lawyer for NRDC and later a member and then Chairman of the Council on Environmental Quality (CEQ, announced, to the surprise and shock of many colleagues, that CEQ favored “a national decision which would make the expanded use of nuclear power contingent on a clear and convincing showing, after consideration of both technical and institutional factors, that nuclear power’s deadly byproducts can be safely contained for geologic periods. ’[188]

Additional pressures to establish an explicit linkage between reactor licensing and the resolution of the waste management question began to mount in May 1979, when the District of Columbia Court of Appeals ruled in the case of Minnesota v. ***NRC.*** [189] The plantiffs challenged NRC’s licensing decision in two cases in which utilities sought to expand their onsite capacity for storing spent fuel. The plaintiffs argued that, absent a proven waste management system, the environmental effects of continued at-reactor storage for an indefinite period of time into the future had to be considered. Moreover, they argued that unless the analysis demonstrated an acceptable level of environmental impact, the additional storage space could not be constructed. While the NRC Licensing Appeal Board accepted the logic of

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[179] *NRDC* v. *NRC*, op. cit.

[180] Ibid., p. 637.

[181] Petition is printed in *Federal Register 42*, Jan. 13, 1977, p. 2730.

[182] “NRDC *petition* for Rulemaking on Waste Management, SECY-77-48B, June 1, 1977.

[183] *NRDC* v. *NRC* and *United* States of *America*, reported in CCH, Nuclear Regulation Reports, pp. 16537-16544.

[184] SECY-77-48B, attachment 1, p. 14.

[185] SECY-77-48B, op. cit., p. 2.

[186] Confidential interviews with author, 1978; also see *Task Force Report*, op. cit., pp. 16-17.

[187] *Report* t. *the President*, final report, op. cit., pp. 5-8.

[188] Quoted in the New *York Times*, Sept. 30, 1977, p. 12.

[189] *Minnesota* v. *Nuclear* Regulatory *Commission*, 602 F. 2d 412 (1979).

the plaintiffs’ contentions, it held that the Commission, in its denial of the NRDC petition, had resolved the issue by stating that it had reasonable confidence that safe methods of permanent disposal would be available when needed.[190] The court, however, felt that such a pivotal statement had to have a firmer analytical foundation than the Commission had thus far provided. The court, therefore, remanded the case to the agency for further consideration in “the interest of sound administration.[191] In October, NRC announced its intention to conduct a generic processing “to reassess its degree of confidence that radioactive waste produced by nuclear facilities will be safely disposed of, determine when any such disposal will be available, and whether such wastes can be safely stored until they are safely disposed of. ’[192] That proceeding, to which there are over 40 parties, is expected to conclude in 1983.

Coping With Interdependence

As the reader is undoubtedly aware, the eight elements of waste management policymaking just presented are not independent of each other. Rather, events transpiring in one sphere affect and constrain later events in all spheres. In this penultimate section, first introduced is a conceptual framework for understanding those interactions; it then is employed to explicate the intricacies of waste management policymaking.

At the outset of this paper, developing the nuclear power energy system was a rather complex task laden with uncertainties. Also noted were those characteristics of complexity and uncertainty that led policy makers to assign a low organizational priority to the issue of waste management up until 1975. Now there is a need to explore further some of the implications of complexity; this time the complexity of the waste management domain itself.

Although there is some disagreement about the concept’s meaning among those who use it, the level of complexity will be associated with the number and richness of the interdependencies that join the components or elements of a policy domain. A policy domain will be complex if it possesses a large number of interdependencies among its elements and if it is structured in a fashion that prevents breaking it down into relatively self-contained systems capable of being treated independently of each other. In engineering phraseology, complexity is what distinguishes tightly coupled from loosely coupled systems. In cybernetic terms, complexity results from the presence of numerous feedback channels. Complexity is what forces econometric modelers to abandon a system of recursive equations and shift to a system of equations that capture a series of reciprocal relations. While no convenient metric exists which scales complexity, a persuasive case can be made that the nuclear waste management policy domain is relatively complex. In figure A-2, the major interdependencies among the domain’s elements are sketched out.

Most of those relationships can be inferred from the analysis of the eight elements of policymaking. The choice of waste form is dependent on whether spent fuel rods or high-level reprocessed byproducts are considered to be waste. But the choice is also determined by how adequate the scientific/technological knowledge base is deemed to be. For instance, those who are skeptical of our current ability to engage in accurate long-term predictions of geologic behavior would choose more sophisticated forms than those who had more confidence. Moreover, regulatory standards, such as the proposed technical criteria recently suggested by NRC, have an obvious influence on the waste form selected. In a similar manner the choice of siting strategy will depend on the adequacy of the knowledge base; the greater the uncertainty, the more redundant the strategy is likely to be. But the siting strategy will also be strongly affected by the requirements of the National Environmental Policy Act as well as specific mandates of NRC such as its licensing regulations.

The capability to develop a system for disposing of radioactive waste will be a function of the siting strategy, the choice of waste form, the adequacy of the scientifichechnological knowledge base, and the thoughtfulness and sophistication of the implementation program. That latter component subsumes, among other things, logistical and budgetary planning, manpower training, designing responses to large changes of scale in operation, and post-decommissioning monitoring. Capability will be influenced as well by the regulatory standards set forth by NRC and EPA; the stricter the standards, the less likely, ceteris paribus, will be the existence of sufficient capability to meet them.

But in an important way, those regulatory standards are also affected by capability. If the regulators, for instance, do not believe that a requirement for zero release for 10,000 years is within the current or near-term projected capability, they will be reluctant to impose it. The standards will be influenced by elements in the regulators’ political environment such as courts, Congress, and by the outcomes of battles among competing interest groups as well.

Like beauty, however, capability is often in the mind of the beholder. Those perceptions will not be independent of some “objective’ assessment of the development act but they will be influenced-perhaps strongly—by

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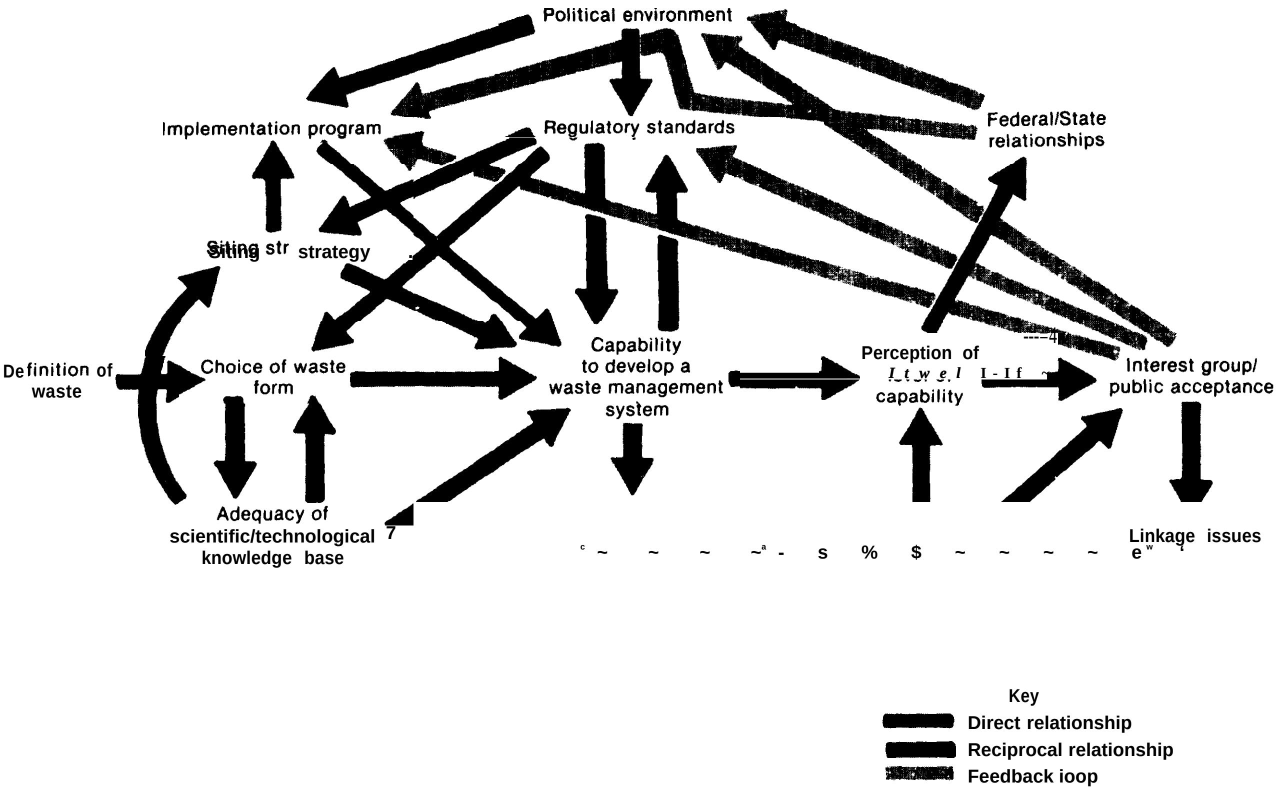
[190] 7 *NRC* 51.

[191] *Minnesota* v, *Nuclear Regulatory Commission,* 418.

[192] *Federal Register 44,* Oct. 25, 1979, pp. 61372-6~3~5.

Figure A-2.—Waste Management Policymaking



other factors as well. For instance, the historical experience of waste management will affect an individual's sense of current capability. Totally exogenous considerations such as political philosophy, value orientation, or lifestyle may also play a role in evoking perceptions of capability.

This distinction between capability and perceptions of it is not a trivial one: for it is the latter factor, not the former one, which directly influences other elements in the policymaking schema. In particular, the activities of interest groups are premised on their particular views about capability. Members of the general public will accept or reject proposed projects based on their beliefs about capability. Moreover, Federal/State relationships will develop in ways determined by perceptions of capability; the less favorable the perceptions, the greater the effort subordination jurisdictions will make to have a strong say in waste management decisionmaking. Finally, those perceptions will affect how salient the linkage issue is likely to be; unfavorable beliefs increase sensitivity to the claim that waste is being produced without any demonstrated means at hand to dispose of it.

These interactions among elements of the waste management policy domain dynamically play themselves out over time. Thus, the definition of waste accepted at time T affects the choice of waste form at time T + 1. In similar fashion, the degree of public acceptance for a particular project or policy at one point in time influences the character of the political environment at some later point. Finally, the reciprocal relationship between choice of waste form and the adequacy of the knowledge base and between regulatory standards and capability can also be understood in terms of a time-lagged interdependence.

The dynamism, critically conditioned by the complexity of the domain, engenders important consequences as policymaking unfolds, Any given element comes to depend in a nonsimple manner on prior states of a range of other elements. Not only need policy makers concern themselves about managing a set of direct relationships, but they also must address a set of indirect ones as well. In less formal terms, the dynamism and complexity of policymaking quickly locks the elements of the domain together. Past decisions and performance come to influence and constrain present choices in important respects. Four examples can illustrate how this process has occurred.

Example One

Adequacy of knowledge -Capability+ Perceived capability-Acceptance

So long as all the major actors in waste management policymaking subscribed to the salt assumptions, consensus prevailed as to the general adequacy of the scientific/technological knowledge base. The clear implication of that consensus was that isolating waste was a quite solvable problem. Certainly that was the thrust of the earliest NAS study. Those not directly involved had no basis for questioning that claim and, thus, overall perceptions of capability were positive. Interest groups and the general public, to the extent they even thought about the issue of waste, were quiescent.

As the consensus began to dissolve in the mid-1970's, questions were raised about capability—with some arguments being advanced that isolation, in principle, was impossible. Within the larger community, perceptions about capability grew more skeptical. As those perceptions became more widespread, they provided the basis for opposition among interest groups and members of the public.

In short, actions taken early on in the history of waste management severely constrained the options available in later years. As the premises which underlay action shifted, the nuclear developers found themselves locked in, unable to respond to changing circumstances without undergoing considerable organizational trauma.

Example Two

Adequacy of knowledge+ Capacity+ Regulatory standards Waste form

The erosion of the consensus about salt, undermining faith in the elegant solution, had additional consequences beyond activating interest groups and members of the general public. Personnel at both EPA and NRC began to ponder what their response should be. At both organizations, skepticism replaced confidence in the accuracy of predictions of geologic behavior over long periods of time. The simple and straightforward assumptions held in the past were seen to be inadequate.

Although EPA's position cannot be ascertained, since the agency has not promulgated its draft standards and criteria, NRC response has been strikingly clear. Those regulators have mandated that the waste form and package become fully capable of isolating the waste independently of the repository and surrounding environment. In other words, given the inadequacy of knowledge and the resulting predictive uncertainties prudence requires that the repository geology not be the sole barrier preventing release of the waste. The waste form and package must maintain its integrity for over 1,000 years. After that, the waste must not escape beyond the engineered portion of the repository at a rate of greater than 10-5 per year.

Example Three

Perception-Federal/State relationships-Political environment Implementation

In the early 1970's, when AEC embarked on the Lyons project, the view was widely held among leaders of the Kansas Geological Survey that insufficient knowledge about repository design had been gathered. The men from Kansas pointed to what they felt were primitive heat-flow models as well as gaps in understanding waste-rock interactions and rock mechanics. These concerns about the technical viability of the effort provided a basis for opposition on the part of U.S. Representative Skubitz and Governor Docking.

Those officials unleashed a barrage of criticism on AEC, and despite the agency's best effort, those protests—asserting that State interests were being ignored —never diminished. Within a year, the controversy had escalated. Kansas Senators Dole and Pearson were persuaded to introduce an amendment to an AEC authorization bill. The rider required that an expert advisory committee be appointed to certify that the Lyons site was sound and the repository design was reliable. Absent such certification, the Commission could not proceed. Had the effort gone ahead, the agency would have lost its autonomy over the project's implementation.

Example Four

Experience with storage-Perception- Federal/State relationships- Political environment- Implementation

Historically, it has been the case that people's judgments about the degree of capability have, rightly or wrongly, been strongly influenced by the record established in storing waste from the military program. Images of leaking tanks at Hanford and the orphaned waste at West Valley subvert claims of competence for disposal. As the images became more widespread and as the waste issue became more salient, State officials began to seek Federal guarantees that would ensure that any project within a State would be predicated on a high level of scientific and technical expertise.

Without those assurances, States were reluctant even to permit repository site investigation, let alone actual site selection. As more and more States espoused that position, a new-era "tragedy of the commons' loomed.

The National Governors’ Association, in response, advanced the idea of consultation and concurrence and soon found it accepted by the Carter administration. Formal agreements were to be negotiated between the States and DOE which would govern the implementation of further repository development activity.

The complexity and dynamic nature of the waste management policy domain—characteristics we have tried to lay out conceptually and with help of the four examples just presented— are not merely intellectual abstractions. Rather, the existence of those two features has some significant real world implications.

First, if our arguments are valid, the past is indeed prologue; the slate can never be wiped clean. Actions taken in the past continue to reverberate within the domain of waste management policymaking. To be sure, the impact of those actions—unless reinforced by later similar ones—becomes attenuated as they recede in time. But the impact never disappears completely. Thus, present day policymakers find themselves saddled with a not-entirely-welcome legacy. Although they may assert that the “time has come to put Lyons behind us, ’ they are indulging themselves if they believe that can easily happen. Past problems will reside in the consciousness of many players.

The most salient consequence of this pertains to the problem of credibility. Even the most objective and scientifically responsible and competent DOE program managers will find that they will be judged not only on their own merits but on their predecessors’ as well. The claim that ‘‘things will now be done right’ will often appear hollow in the face of a string of past failures and incomplete successes. Altering that perspective will not be a trivial undertaking.

A second implication of the complexity and dynamism of the waste management policy domain follows from the first. At this point in time, 35 years into the nuclear age, there is only limited room for new failures in dealing with those toxic materials. Certainly, the current program is substantially improved in terms of resources, broader organizational commitment, and sophistication compared to the one in place as recently as 5 or 6 years ago. A sense prevails that progress-albeit slow progress in some people’s view—is being made. Yet, the optimism is fragile. There simply is not much “slack” present. Should a glaring error arise, there will be little or no residuum of good will to buffer the program from profound shocks.

Conclusions

On the basis of the discussion in the preceding 10 sections, a range of conclusions can be drawn about how waste management policymaking has evolved over time. For ease of presentation, the findings will be categorized as follows: conclusions about the policymaking process; conclusions about the technical basis for policymaking; conclusions about problem-solving strategies; and conclusions about the institutional dimension of policymaking.

The Policymaking Process

Up until approximately 1975, waste management and particularly waste disposal efforts were fragrnented from and subordinate to other aspects of nuclear development. That state of affairs was an expectable organizational response to uncertainty and complexity. Waste management and disposal was funded at low levels; the problem had low bureaucratic visibility; research and development directed toward disposal was quite rudimentary.

Waste management policies have shifted frequently over the years. Initial plans to construct a repository at Lyons, Kans., had to be abandoned in 1972. AEC then pursued a policy of extended surface storage until 1975. Those efforts were replaced by a program emphasizing disposal in salt formations. More recently, the program has looked at an expanded range of potential candidate sites in a variety of geologic media.

Major waste management policies were made on an incremental and ad hoc basis. The waste management program has lacked a unified guiding philosophy that could lend coherence to decisionmaking. Policymaking has tended to be reactive rather than proactive. It has often had a short-term rather than a long-term orientation.

Difficulties encountered in one sphere of waste management have often created problems in other spheres. Developing a waste disposal system requires the fine tuning of a number of interdependent components. When difficulties arose in one sector, they carried over into other parts of the system. As a result, problem-solving was retarded in a wider number of areas.

Waste management policymaking retains little slack to buffer against additional setbacks. Many of those involved in the waste management policy domain hold the view that the program has been relatively unsuccessful. Those negative images have damaged the program’s credibility. In many quarters, no residuum of good will exists to mitigate the shock of some new policy failure.

Technical Issues

Although uncertainties ***over some technical questions persist, no one has suggested that waste disposal in geologic formations is, h principJe, not possible.*** Many technical issues remain unresolved. Disagreements remain about the significance of those issues and corresponding policy consequences. Nevertheless, throughout the history of waste management problem-solving, no credible argument has emerged which undermines the feasibility of geologic disposal.

After an initial overwhelming emphasis on disposal in salt formations, attention has increasingly been given to candidate sites in other media. For many years, AEC, heavily influenced by NAS, was committed almost exclusively to finding a site in salt. Not until the mid- 1970's did ERDA expand the range of potential host formations. DOE has broadened even further investigations and research into sites other than salt.

Although more is known about engineering a repository in salt, no particular host geologic formation enjoys a preferred status as a potential disposal site. Geologic knowledge has evolved since the early 1950's when salt was recommended as the preferred disposal media. A technical consensus has emerged which holds that the repository and its hydrogeologic environment must be analyzed in tandem to ensure the isolation of the waste. Once that environment has been factored into disposal design, most geologists believe that suitable sites can be found which utilize a wide variety of host rock formations.

Waste forms and packages have evolved from being mere conveniences to becoming fully redundant components of a disposal system. The attention paid to waste form early on was mainly directed at increasing the ease of transportation of the material from a reprocessing plant to the repository. Later, ERDA advocated other waste forms that would increase the middle term isolation capability of a disposal system. In 1981, NRC issued a proposed regulation that elevates waste form and packaging into a major component whose performance strongly affects the very-long-term isolation capability of the system.

Strategic Issues

Until 1978, the strategy for seeking disposal locations focused on a single site at a time; no site intercomparisons were to be made prior to site selection. Personnel at AEC and ERDA adopted this strategy of single site investigation in part because they had to operate on tight budgets. They also saw no reasons why comparing sites offered any safety advantage. Current NRC procedural regulations, however, require some site intercomparison prior to the issuance of a repository construction permit.

A single site strategy can be politically risky. The nuclear developers must operate in a political atmosphere characterized by suspicion and skepticism. No jurisdiction is enthusiastic over the prospect of being a host for a repository. If only one site is under active consideration at a time and no alternative exists, that suspicion and skepticism becomes reinforced and local opposition intensifies.

Nontechnical considerations have played an important initial role in selecting sites to date. It is largely immaterial whether technical or nontechnical factors are considered first in choosing a potential repository site so long as both can exert an unbiased influence in the process. Tentative site selection in Kansas and in New Mexico relied heavily at the start on nontechnical factors. Concerns were raised in each case that technical considerations were not given their appropriate weight.

Institutional Issues

The definition of waste, whether it includes spent hel as well as ***high-level reprocessed waste, has important implications for decisions about storage and disposal.*** Historically, the waste management program had presumed that reprocessed waste would be disposed of. As that assumption came under challenge and was undermined, adjustments—some of which ***were*** major—had to be made in the program. The current waste management program seeks to avoid those difficulties in the future by designing facilities that will accommodate either reprocessed waste or spent fuel rods.

Repository development has been complicated by the absence of regulatory standards. The nuclear developers have proceeded over the years to design repositories and investigate potential sites without much regulatory guidance. This has had two consequences: first, emerging regulations have forced the developmental program to make time-consuming and costly adjustments. Second, the developmental program encountered public suspicion and skepticism because its internal standards and criteria were unaccountable.

Policies predicated on extended storage have enjoyed acceptance only when coupled with strong commitments to and implementation of a credible program of disposal. The Federal Government has advocated long-term waste storage on at least four different occasions. Each time public criticism has been intense. Only when the plans for storage were linked to a well-funded disposal program did the opposition become somewhat attenuated.

Federal/State relationships have evolved with the States being given a more active role in waste disposal policymaking. Initially the State role was one of technical collaboration. State concern over repository siting decisions coupled with their informal powers to delay Federal effort augmented that role. Current policy with regard to commercial waste disposal envisions a major State contribution in siting choices.

Pressures to establish a formal linkage between further generation of commercial waste and progress to-

ward solution of the disposal problem have grown over the years. Prior to 1975, there were very few who advocated that linkage. Thereafter, however, a number of States adopted laws conditioning further growth in nuclear generating capacity on a resolution of the waste issue. NRC is currently holding hearings to determine its stance on the question.

In this paper, the major themes and issues in the history of waste management policymaking have been detailed. By understanding the successes and failures that marked that history, people might in the future avoid policies that are error-prone. Therein lies the potential contribution of this research.