AN ANALYSIS OF LOW LEVEL RADIOACTIVE WASTE BURIAL SITE CAPACITY PROJECTIONS

Prepared By
Janet Gorn-Braun
U.S. Nuclear Regulatory Commission

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1.0 Introduction

1.1 Background

One important part of the Nation's commercial nuclear industry that is yet to be fully established is a national low-level waste management system. Inclusive in this system are the institutions, activities, facilities, and regulations, which are necessary to collect, handle, treat, transport, store, and ultimately dispose of low-level radioactive waste products. Development of this key element in the industry was postponed for years, while efforts were concentrated in creating the nuclear-power electrical generating system and its associated support facilities. Now the increasing generation of low-level radioactive waste from an expanding nuclear industry, coupled with recent events surrounding the uncertainties regarding the disposition of adequate shallow-land burial sites, has created an urgency to intensify development of a low-level waste management system.

Establishing a waste management system not only encompasses a technological challenge, but significant social, political, and ethical questions as well. Resolution of problems surrounding such a system requires no breakthrough in nuclear physics nor even the development of a radically new engineering technology. What is required is the application of reasoned judgement in identifying and assessing the various facets of the problem. Indispensable to the judgement and assessment activities for the planning and design of methods and facilities that will be needed for low-level radioactive waste management, is a technologically valid projection of the quantities of radioactive wastes that will be generated by the commercial nuclear industry and consigned to shallow-land burial sites.

The purpose of this study is to provide an analysis of projection trends used in comprehensive forecasting of commercial shallow-land burial site capacity for low-level radioactive wastes, to evaluate the reliability of conclusions drawn by forecasters, and to access the Nuclear Regulatory Commission's need to take a more active role.

1.1.1 Current Disposal Site Status

The United States Government has been generating low-level radioactive wastes in defense and other government programs, since the inception of the nuclear weapons (Manhattan) project in World War II. All these wastes, along with those generated from minor commercial activities, were disposed of at the Atomic Energy Commission (AEC) shallow-land burial facilities or by ocean disposed burial.* When it became apparent that commercial activities within the private sector would generate low-level radioactive wastes in significant quantities, consideration was given to the possibility of developing commercial sites. After the determination was made that sites could be safely developed and operated by non-federal management, the AEC announced a new regulatory policy,[1] that stated commercial sites were to be established on federal or state land, and operated by private firms under Atomic Energy Commission or Agreement State license.

The AEC licensed the first commercially-operated shallow-land burial site in 1962 at Beatty, Nevada. Since that date, commercial management expanded to include three private companies operating six sites. The sites are

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*No licenses for sea disposal were issued after 1960, and the U.S. discontinued this method in 1970, following the recommendation of the Federal Council on Environmental Quality (CEQ).

located at Maxey Flats, Kentucky; Beatty, Nevada; Sheffield, Illinois; Barnwell, South Carolina; West Valley, New York; and Richland, Washington (Figure 1) The three companies licensed to operate the sites are U.S. Ecology, Inc. (formerly Nuclear Engineering Company (NECO)) at Washington, Nevada, Illinois, and Kentucky; Chemical Nuclear System, Inc. at South Carolina; and Nuclear Fuel Services at New York.

Five of the six sites are located in Agreement States and are regulated by the States. However, the Nuclear Regulatory Commission licenses special nuclear material (SNM) in the commercial sector which exceeds formula quantities.* The burial site not located in an Agreement State is Sheffield, Illinois, and it is regulated by the NRC although the State licenses and controls activities at the site concerning naturally occurring and accelerator-produced radioisotopes (NARM) - not subject to NRC's control. All the burial grounds are on state owned land with the exception of Hanford, Washington. For all sites the state has commitments for assuring long-term care and maintenance of the site, although responsibility for the Hanford site will eventually revert to the Federal Government.

Of the six original sites, only those in Washington, Nevada, and South Carolina, are presently operational and considered viable for disposal operations (Table I).

The first to close was the burial site at West Valley, New York. The site operator, Nuclear Fuel Services, voluntarily discontinued operations on

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*Formula Quantity = 300g U-235, or 200g U-233, or 200g PU or any equivalent combination.

FIGURE 1

COMMERCIAL LOW-LEVEL RADIOACTIVE WASTE DISPOSAL SITES

TABLE I

COMMERCIAL LOW-LEVEL WASTE BURIAL GROUNDS

Year Open	Location	Operator	Originally Licensed by	Currently Licensed by	TRU Accepted	Operational Status
1962	Beatty, Nevada	NECO*	AEC	State & NRC**	<10 nanocuries/ gram	Open
1962	Maxey Flats, Kentucky	NECO	Kentucky	State	<10 nanocuries/ gram	Closed December 27, 1977[a]
1963	West Valley, New York	NFS***	New York	State	0.1 gram PU/ft^3 other elements, yes	Closed March 11, 1975[b]
1965	Hanford, Washington	NECO	AEC	State & NRC**	<10 nanocuries/ gram	Open
1967	Sheffield, Illinois	NECO	AEC	NRC	<10 nanocuries/ gram	Closed March 8, 1979[c]
1971	Barnwell, South Carolina	Chem-Nuclear Systems, Inc.	South Carolina	State & NRC**	<10 nanocuries/ gram	Open

* Nuclear Engineering Co., Inc. (NECO)
** NRC licenses only Special Nuclear Material
***Nuclear Fuel Services (NFS)

[a]Burial was suspended on December 27, 1977 due to leakage in trenches that resulted in on-site migration of buried material

[b]Burial was suspended on March 11, 1975 due to seeping water containing tritium and ^{90}SR from two trench caps

[c]Burial was suspended on April 8, 1979 due to filling of available capacity

March 11, 1975, because water containing tritium and strontium-90 was seeping from two of the trench caps.

The second burial site facility to discontinue operation was Maxey Flats, Kentucky on December 27, 1977. Waste burial was temporarily banned by state officials for a safety study after it was found that leakage in trenches had resulted in some on-site migration of burial waste material. The site was permanently closed in 1978.

The third site to close was Sheffield, Illinois on April 8, 1978. The last available trench had been filled. The Nuclear Engineering Company applied for a license for future burial space, and when hearings were pending, the company decided to withdraw its application for expansion and announced it was terminating its license to operate the facility. Subsequentlythe Nuclear Engineering Company was notified that licensees cannot unilaterally relinquish their responsibility and the company was ordered to maintain the site.

With the closing of three of the six sites, a severe regional imbalance emerged from the locations of the remaining sites. This imbalance was aggravated in 1979 when the Governors of Nevada and Washington, because of various shipping and packaging irregularities, placed a temporary embargo on waste acceptance with the opening and closing of sites. The site at Beatty, Nevada closed for the first time on July 2, 1979 and re-opened on July 24, 1979, and for the second time on October 23, 1979 re-opening on December 10, 1979. The site at Richland, Washington only closed once on October 4, 1979, reopening on November 19, 1979.

The Governor of Washington and the Governor of South Carolina also placed a limit on waste volume to be accepted. South Carolina limited waste to 100,000 ft^3 on October 1, 1981. Washington announced plans to exclude all out-of-state waste with the exception of medical waste after 1982. A State initative passed in late 1980 moved this date up to July 1, 1981. The U.S. Department of Justice filed suit against the State's ban and a subsequent Court ruling declared the ban unconstitutional.*

The Governor of the State of Nevada attempted closing the Beatty site permanently when the site operators applied for a license renewal in 1980. The State licensing board however approved renewing the license. That decision is now undergoing additional State review (license is still in effect and considered in a state of "Timely Renewal").

The present physical capacity of the three open sites is estimated to be adequate to meet disposal requirements until 1985 (Table II).

1.1.2 New Disposal Site Status

From 1962 until 1969, siting and location of new low-level radioactive waste burial grounds was based mainly on initatives of private operators. Site suitability was based on evaluation of individual radiation-safety merits, and licenses were issued or denied on that basis. In most instances little consideration was given during licensing reviews to the actual need for a burial ground in a specific region and at a specific time. In some cases, siting was promoted by a state to provide capabilities chiefly or

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* United States of America vs State of Washington, et al., C-81-190, June 30, 1981.

TABLE II

STATUS OF LAND USAGE AND AVAILABILITY AT COMMERCIAL BURIAL SITES[a]

SITE	STATUS	SITE SIZE (hectares)	LAND UTILIZED (hectares)	LAND AVAILABLE (hectares)
West Valley, NY	Closed	8.9	5.8	b
Maxey Flats, KY	Closed	102	66.8	c
Sheffield, IL	Closed	8.9	8.9	d
Barnwell, SC	Open	104	39.2	64.8[e]
Richland, WA	Open	40.5	2.0	38.5[f]
Beatty, NV	Open	32	7.3	11.3[g]
Total	--	296	130	115

a. Source: U.S. Department of Energy. August 1980. Spent Fuel and Waste Inventories and Projections. Report: ORO-778. OakRidge Operations Office, Oak Ridge, Tn.

b. Burial was suspended on March 11, 1975.

c. Burial was suspended on December 27, 1977.

d. Burial was suspended on April 8, 1979.

e. Expansion of this site is planned, although the area available has not been determined.

f. The 40.5-hectare site is part of 405 hectares which the State has leased from the Federal Government. The 364.5-hectare tract may be available for future waste burial.

g. Approximately 162 hectares could be purchased and added to the site if expansion were allowed.

exclusively for the state's nuclear industry.

With the passage of the National Environmental Policy Act in 1969 (NEPA) (83 STAT 5841), NRC was required to use a cost/benefit analysis as a mechanism to consider the need for sites licensed and to consider alternative licensing decisions. The states, under the terms of their agreements, were not required to comply with NEPA, but in 1974, the Atomic Energy Commission sent a letter to all Agreement States requesting that the national need for burial grounds be considered to minimize environmental impacts and to control site proliferation. The states complied with the request.

The passage of NEPA also caused a wide range of Congressional, technical, industrial, public, and government groups to give serious attention to the disposal of low-level radioactive wastes by shallow-land burial and radioactive waste management. In June 1974, the General Accounting Office (GAO) initiated a review of waste burial grounds and presented Congress with a final report on January 12, 1976.[2] The report addressed both commercial burial grounds and technological practices, finding that:

- No systematic site selection process was practiced.
- Site criteria had not been established, and characteristics at existing sites varied greatly.
- Radiological problems had begun to develop at some sites, and radioactivity migration had been detected.
- Recordkeeping practices at disposal sites needed improvement.
- There was slow progress in getting an Agreement State licensee to implement effective corrective action.

Consequently, as a result of the 1976 GAO report, Congressional hearings were held during February, March, and April 1976, by the Conservation, Energy and Natural Resources Subcommittee on the House Committee on Government Operations. In House Report No. 94-1320,[3] dated June 30, 1976, the Committee reported it found that management and regulatory responsibilities for low-level radioactive waste disposal were dispersed throughout the Federal and State governments and were without consistent direction and coordination. In addition, it found that the performance of existing disposal systems was not uniformly good and radioactive waste migration had occurred. The Committee put forth seven recommendations, and two of those recommendations affected new siting and inventory:

Recommendation (2): State-Federal authorities and programs concerning site operation and financial and technical assistance should be clarified and a comprehensive policy developed.

Recommendation (4): Agencies should collect data on radioactive wastes already disposed and projected to be disposed.

The Subcommittee on Environment and Safety of the Joint Atomic Energy Committee (JAEC) also held hearings in May 1976.[4] During the hearings the Committee questioned whether the newly created NRC, in view of the current problems at the low-level radioactive waste sites, had control over the activities of the Agreement States in the management of radioactive wastes. The NRC testified that it was presently involved in a reassessment of waste management issues, and described its plans to review the Federal/State regulatory roles for low-level waste management established under the Atomic Energy Commission.

In response to the GAO report and the Congressional hearings, NRC established a Task Force to review the Federal/State Program for regulation of commercial low-level radioactive waste burial grounds. The Commission issued its final report in January 1977.[5]

The increased attention on the low-level radioactive management issues gave rise to three very distinct points of view in regard to regulating commercial waste by December 1976:

A. Congressional Viewpoint

Congress strongly leaned toward NRC exercising licensing and regulatory authority over low-level radioactive waste management rather than states. This recommendation was based not so much on the states' ability to regulate, as on the premise that low-level radioactive waste was a national problem, requiring centralized control for standards development, environmental assessment, licensing, decommissioning, and long term care and maintenance.

B. States Viewpoint

States believed they have an important role in the licensing of low-level radioactive waste burial grounds within their own borders, since they have traditional responsibility for assuring the health and safety of their citizens (although opinions among State Officials varied as to how a state should fulfill its responsibility).

C. NRC Viewpoint

The Commission took a strong policy position, in regard to developing new low-level radioactive waste disposal sites, based on the conclusions reached by the NRC Task Force on review of the Federal/State program for regulation of commercial low-level radioactive waste burial grounds. The Task Force found that the present system for low-level radioactive waste management lacked national organization and direction. The states, in discharging their regulatory duties, have operated under difficult circumstances, but have adequately protected the public health and safety. There is no compelling health or safety reason for reassertion of Federal control. However, the states do not have the resources to provide the needed overall leadership or organization, nor do they have the obligation to find solutions to the national problem of waste management. The development and implementation of such a plan can be more readily achieved if the NRC assumes regulatory control (with state participation). The Task Force further identified the need to investigate alternative methods for waste disposal and to develop standards and criteria. An additional need was to better define capacity requirements on a regional basis. The continued licensing of shallow-land burial sites prior to the evaluation of alternative methods of burial and regional planning, could result in site proliferation of what is less than optimum disposal method. The Task Force estimated that the six sites (all six were operational) would provide sufficient capacity until 1990. Until a need to expand capacity or a national low-level radioactive waste management program has been established, licensing or additional low-level waste disposal is unlikely to be in the best public interest.

In 1977 two significant events took place that directly impacted new disposal sites as well as recharting the direction of low-level radioactive waste management efforts. The first event was the enactment of P.L. 95-110 repealing Chapter 17, of the Atomic Energy Act of 1954, thus abolishing the Congressional Joint Atomic Energy Committee. With the disbanding of the JAEC, all functions and oversight responsibilities were reassigned to several Senate and House Committees effective September 20, 1977. These committees became actively involved with radioactive waste management issues, and began to introduce numerous pieces of legislation to address the problem.

The second event was the inauguration of Jimmy Carter in January 1977, and the beginning of a new Presidential Administration. After taking office, President Carter took a series of important actionsto address nuclear issues. As part of the National Energy Plan, he ordered a review of the U.S. nuclear waste management program. This action led to the creation of an internal Department of Energy task force which carried out the review directive issuing a report in February 1978 (Deutch Report).[6]

The report set forth preliminary views on key issues in the radioactive waste management area, and highlighted the need to develop a national nuclear waste management policy and integrated program. On March 13, 1978, in response to the findings, the President established the Interagency Review Group (IRG) to formulate by October 1, 1978, recommendations for the establishment of an Administrative policy with respect to longterm management of nuclear wastes and supporting programs to implement the policy.[7] The Task Force was chaired by the Secretary of Energy and representatives of fourteen government entities.* The final report was issued in March 1979,[8] and the IRG recommendations ultimately formed the basis of the President's policy statement outlining a Comprehensive National Radioactive Waste Management Program.

The President announced the nation's first national radioactive management program on February 12, 1980.[9] It contained a number of key elements for the management of low-level radioactive wastes. Among those key elements were several directly affecting new site disposal:

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*Department of Energy; Department of State; Department of Interior; Department of Transportation; Department of Commerce; National Aeronautics and Space Administration; Arms control and Disarmament Agency; Environmental Protection Agency; Office of Management and Budget; Council on Environmental Quality; Office of Science and Technology Policy; Offfce of Domestic Affairs and Policy; National Security Council; Nuclear Regulatory Commission.

1) The DOE was directed to prepare a National Waste Management Plan to be updated biannually that was to include plans for low-level radioactive wastes;

2) The DOE and NRC was directed, until such time as additional disposal facilities are sited and licensed, to assist states in setting up interim storage facilities;

3) Legislation to assist states in managing commercial low-level radioactive waste and the authority to enter into regional organizations or compacts for the operation of the sites was to be submitted to Congress;

4) The DOE was directed to work with the states in their efforts to establish a reliable commercial low-level radioactive waste disposal system;

5) The DOE was directed to work with the states to assist in their activities to establish regional disposal sites for low-level wastes from the fuel and non-fuel cycles; and

6) To involve all levels of government in sharing the responsibility for safe management and disposal of nuclear wastes, the President created, by Executive Order 12192, a State Planning Council on Radioactive Waste Management (SPC) to advise the Executive Branch and the Secretary of Energy, and work with Congress in making and implementing decisions on radioactive wastes. The SPC was directed to give low-level radioactive waste management early, priority attention.

By the close of the Carter Administration in early 1981, national sensitivity to low-level radioactive waste issues had generated a number of actions to address proposed plans, notably in the area of new sites. All areas of interest contributed to defining low-level radioactive waste management based upon state or regional responsibility.

The Department of Energy had prepared and issued a working draft National Waste Management Plan,[10] and Congress in December 1980 passed P.L. 96-573, the Low-Level Radioactive Waste Policy Act (95 STAT 3347), establishing Federal Government policy on low-level radioactive waste:

A) Each state is responsible for providing for the availability of capacity either within or outside the state for the disposal of low-level radioactive waste generated within its borders;

B) Low-level radioactive waste can be most safely and efficiently managed on a regional basis; and

C) To carry out the policy, states may enter into Congressionally approved state compacts.

The Nuclear Regulatory Commission had completed its examination of alternate methods of low-level radioactive waste disposal,[11] and issued a draft rule (10 CFR 61) in support of siting and management technology for near-surface land burial (1979). Additionally, on Novemeber 7, 1979, Commission Chairman, Joseph Hendrie, testified before Congress in support of a state site thrust for disposal responsibility.[12]

The Commission felt that while Federal planning would reduce the possibility of unnecessary disposal site proliferation, the same might be accomplished by the States through compact arrangements on some pro quo basis. New sites were needed (with only 3 of the original 6 still in operation), and it had been demonstrated that states can perform the technical assessment successfully.

In support of the Low-Level Radioactive Policy Act (95 STAT 3347), the Commission revised its Statement of Policy regarding agreements with states, and criteria for guidance in discontinuance of NRC regulatory authority, and assumption of regulatory authority by states through the State Agreement Program. This policy revision allows interested states to enter into agreements with NRC to regulate only low-level radioactive waste sites (46 FR 7540).

The SPC Presidential Task Force had compiled with the President's directive to give low-level radioactive waste management early, priority attention by passing the following resolutions, at the beginning of its tenure:[13]

- Resolution 2-2: Every state is responsible for the disposal of low-level radioactive waste generated within its boundaries, and states should enter into compacts, as necessary, for carrying out this responsibility.
- Resolution 4-15: Each state develop a comprehensive plan for the management of its low-level waste generated within its borders.
- Resolution 4-17: Host states or regional compacts should be authorized by Federal statute to exclude from their disposal sites waste generated outside the state or the region.
- Resolution 4-21: The Atomic Energy Act be amended to clarify NRC authority to enter into an agreement with a state solely to authorize state regulation of the disposal of low-level radioactive waste.
- Resolution 4-20: Congress enact legislation to ensure that Agreement States meet nationally uniform minimum standards.
- Resolution 4-18: Congress authorize NRC and DOE to provide technical and monetary support by the appropriate mechanisms to individual states for the development of sites for regional use.

Passage of the Low-Level Radioactive Waste Policy Act (95 STAT 3347) served as a catalyst for a number of states and regional organizations to begin efforts to establish new sites:[14]

- Northwest Interstate Compact (Idaho, Washington)
- Southwestern States (Western Interstate Energy Board)

- South Central Region (Kansas, Oklahoma)
- Southeast Compact (Southern States Energy Board)
- Mid-Atlantic Region (Delaware, Maryland, West Virginia, Virginia, Kentucky, Washington, D.C.)
- New England (Massachusetts, New Hampshire, New York, Pennsylvania, New Jersey)

A number of states have conducted comprehensive assessments of their in-state low-level radioactive waste inventories, issues, and options:

- Arizona
- Florida
- Kentucky
- Illinois
- Maine
- Massachusetts
- North Carolina
- Oregon
- Texas
- Tennessee
- Virginia[15]

1.2 Scope and Objective

The current approach to low-level radioactive waste management is based upon state or regional responsibility. The recently passed Low-Level Radioactive Waste Management Policy Act formalized the approach as a national policy. The role of Federal agencies at this point is to support states in planning for low-level waste management, whether on a single-state or regional basis, and implementing those plans.

One such support function is to provide generation data to aid in establishing a basis for sound waste management. This analysis identifies and evaluates the quantitative characterization forecast studies, projecting expected quantities of low-level radioactive wastes to be generated and disposed of, at commercial shallow-land burial sites through the year 2000. Generation forecast studies considered in the analysis are comprehensive projections that combine data from both fuel cycle and non-fuel cycle sources.

The scope of this study includes a thorough search of technical literature in the public domain to identify and investigate all radioactive waste forecast projections. Studies specifically addressing selective forecasts were examined, but not included within the scope of this analysis. The decision was based on the number, subject approach, methodology, and applicability to site capacity forecasting.

At the onset of this analysis, two objectives were identified. The first objective was to examine the basis for each forecast study to determine whether or not sufficient operating data and historical data were available, to permit the forecasters to draw valid conclusions about the amounts and types of low-level wastes that will be generated in the future, or about the useful life of existing licensed commercial shallow-land burial sites.

The second objective was to examine the Nuclear Regulatory Commission's regulatory responsibility and statutory authority, to take an active role in characterizing data for forecasting quantities of low-level radioactive wastes, and inter-agency activities to support a common data base.

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11. U.S. Nuclear Regulatory Commission. Evaluation of Alternative Methods for the Disposal of Low-Level Radioactive Wastes. Report: NUREG/CR-0681. July 1979.

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13. State Planning Council on Radioactive Waste Management. Interim Report to the President. February 24, 1981.

14. State Planning Council on Radioactive Waste Management. Docket Book: Sixth Meeting. June 8, 1981.

15. Kathleen Newsome-Schneider, Office of State Programs, U.S. Nuclear Regulatory Commission, personal telecommunication with J.G. Braun U.S. Nuclear Regulatory Commission, Division of Waste Management, June 1, 1981.

2.0 Waste Data Sources and Limitations

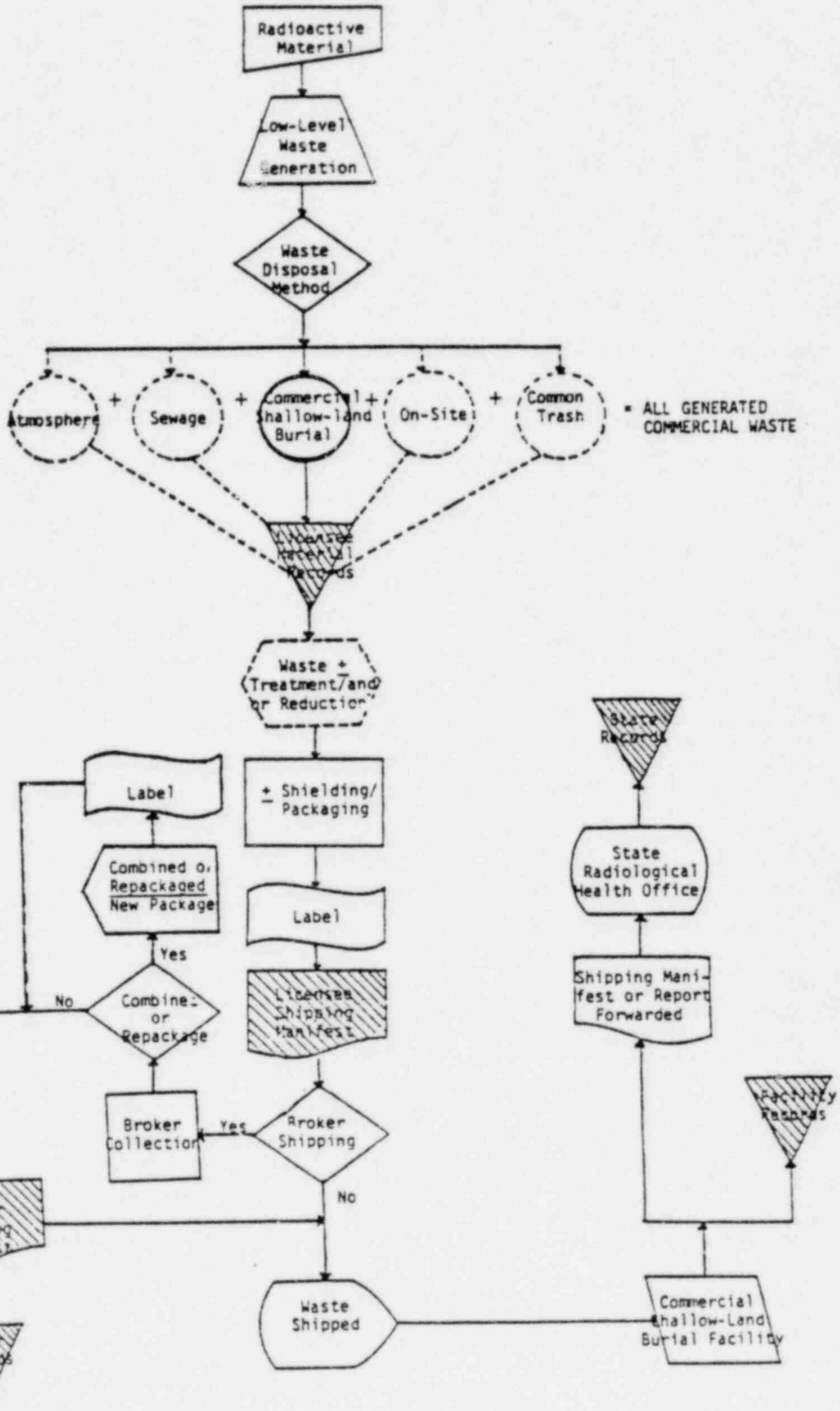
There are three data sources available for preparing low-level radioactive waste forecasts: generator license records, shipping manifest records, and burial site records (Figure 3). All material and facility licenses are required to maintain detailed records (10 DFR 20.401) with regard to radioactive materials for audit and inspection, however there are no requirements for selection or aggregate reporting of such data. Therefore no central common data base is available for modeling or analysis of generator data.

Radioactive material transfer records (10 DFR 71.62) are also required, and shipping manifests (49 CFR 170-189/Proposed 10 CFR 20.311) accompany low-level radioactive waste in transit. In addition, site owners and shipping broker companies retain a copy of the manifest. Generators or brokers prepare packaging labels and shipping manifests (brokers sometimes repackage or consolidate shipments under one manifest).

Disposal site operators are required to maintain records and must rely on package labels or shipping documents to maintain records of waste burial. To avoid exposing workers to radiation, disposal site operators usually do not open waste packages to validate package or manifested information.

With past practices, many waste package labels or shipping documents contained only general information on the waste form, composition, or isotopic content of the waste. Burial site records reflect this information.

FIGURE 3



JGD/81

Waste Form(± Waste and/or Treatment + Volume Reduction) + Shielding/ Packaging = Buried Waste

Disposal site reporting requirements to the state vary from state-to-state. South Carolina requires a microfich copy of the shipping manifest be sent to the State Radiological Health Office, where it is entered into a computerized system.[1] The State of Washington also requires a copy of the manifest be sent to the State Radiological Health Office.[2] Nevada requires totals to be sent; however they are reviewing the possibility of receiving a more detailed monthly report.[3]

Data extrapolation from burial site or state inventory records has a number of inherent information reliability problems, and are therefore limited in modeling or analytical utility for the following reasons:

1) Information is dependent upon the recordkeeping of the generator and/or shipping broker.

2) There is no uniform system of recordkeeping for the generators, shippers, burial sites, or states.

3) Data entry and data transfer errors are inevitable.

4) It is reasonable to assume that several inventory records will be missing in all inventory recordkeeping.

5) Information is often consolidated or generalized, and not adequate to characterize quantiatively - unique contribution as a data element is hampered.

6) The facility and site operator may round-off figures used, thus resulting in differences.

7) Estimated rather than posted data may be used and not designated as such.

8) Propriety record agreements between brokers and generators often prohibit certain types of breakdowns in data used.

9) Generator information is sometimes misleading - shipments may be listed as having originated from a state where it was not generated, because brokers list con-

> solidated waste as originating from the state of the broker's home office.

For the past decade, there has been evidence of efforts to improve recordkeeping, for example:

> The University of Colorado Medical Center found that maintaining an accurate and current inventory of radioactive nuclides was both difficult and tedious. In an effort to keep pace with the ever-increasing use of radioactive materials, a number of non-automated inventory methods were tried and found to be inadequate, and often introduced additional complications. To help solve the dilemma, the University invested in an automated digital computer recordkeeping system. The introduction of this computer recordkeeping system not only reduced the burden of maintaining an accurate and current inventory, but provided unanticipated benefits, which contributed to a more efficient method of control and use of radioactive materials.[4]

It is believed the majority of generators however still use a non-automated system of recordkeeping.

Site operators and state radiological offices have also investigated automated record systems to improve shallow-land burial site management. The first use of an automated system began with the Maxey Flats, Kentucky site in 1972. Leakage in the trenches resulting in off-site migration of burial waste material provided an incentive to closely examine the burial inventory records. The Kentucky Radiological Health Department, under contractual agreement with the U.S. Environmental Protection Agency, automated burial site inventory records from 1963-1972.

The data transferred during the project comprised nearly 200,000 computer cards. Each data record on the computer tape contained up to 25 separate pieces of information or data elements: burial date, burial location, isotope buried, isotope activity, volume, etc.

This project is conspicuously illustrative of automated record compilation problems that occur with historical inventory records, and the analytical or modeling complications that may result:

1) Information transfer errors from shipping manifest to inventory records for the site.

2) Information transfer errors from inventory records to computer cards.

3) Inaccurate information on the original shipping documents (e.g. failure to identify the isotope properly, failure to associate the correct isotope in the shipment with the listed activity, failure to list the complete details needed for inventory, etc.).

4) Some known shipments of large quantities of radioactive material information missing from inventory data records.

5) Possibility of one or more shipments of radioactive material information missing from inventory data records.

6) Differences in recorded quantities versus actual quantities contained in individual shipments - biased toward exaggerating the recorded quantity (it is well known that the best place to tally "Material Unaccounted For" is in the waste shipment).

7) Estimates of the activity content in a shipment were sometimes arbitrary.

8) Discrepancies between statistics reported at the site and elsewhere - some due to reporting methods.

Bad records encountered amounted to 15% of the total. The project attempted to reduce this figure by computerized correction, and tracing of individual records through the shipping records to the generator (a formidable task). The project concluded by recommending that about 15% should be added to all activities on the site to accomodate for bad and missing records.

The second use of an automated inventory record system is the Barnwell, South Carolina site. The State Radiological Health Office requires the site operator transfer a copy of the shipping manifest to the State Office where it is transferred to an automated data system.

The proposed Rule for low-level radioactive waste shallow-land burial 10 CFR 61 (46 FR 38081-38105) addresses many of the data record problems encountered in the past. Improved methods for record keeping and manifest reporting have been incorporated.

2.1 Statutory Mandates and Constraints

Low-level radioactive waste data collecting activities historically have been heavily influenced by Congressional statutory mandates and constraints, and this in turn has influenced forecasting and assessment capabilities. First by legislation, such as the Atomic Energy Act of 1954 and the National Environmental Protection Act of 1969, impacting the stringent regulatory and licensing data record requirements placed on the private sector. Second by legislation impacting the regulatory information collection and paperwork burdens:

1) The Regulatory Flexibility Act of 1980 (P.L. 96-345) obligating agencies to fit regulatory requirements to the scale of the affected activity, and to lessen the economic impact to small business entities.

2) The Paperwork Reduction Act of 1980 (P.L. 95-511) tightening the oversight authority of the U.S. Office of Management and Budget (OMB), and increases the requirements of the clearance process needed before information requests can be made of the public.

And third by legislation impacting specialized data reports required by Congress:

1) The Hazardous Substances Releases, Liability, Compensation Act of 1980 (P.L. 96-510) or Superfund Act requiring EPA to conduct a study that will include an assessment of current and projected treatment, storage, and disposal capacity needs and short falls for hazardous waste (includes radioactive) by management category on a state-by-state basis, and an evaluation of the appropriateness of a regional approach.

2) The Low-Level Radioactive Waste Policy Act of 1980 (P.L. 96-576) shifting disposal capacity responsibility to the states (remaining under NRC regulation directly or indirectly through the Agreement States Program), and requires DOE to prepare and submit to Congress and to each state within 120 days a report on the disposal capacity needed for present and future low-level radioactive waste on a regional basis, and to include an inventory of types and quantities of waste (DOE Report: DOE/NE-0015).

All developers involved in forecasting activities must take into consideration, both the technological and administrative directives incorporated in statutes affecting federal agencies, as well as the inherent problems found in recordkeeping, mathematical modeling, and statistical projections.

2.2 References

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4. Ibbott, Geoffrey S., et. al. "Record-Keeping In A Radiation Safety Office By Timesharing Digital Computer", Health Physics, Vol. 21, October 1971, pp. 581-584.

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3.0 Waste Projections

The essential elements of a satisfactory national low-level radioactive waste management program are those that provide for:

a) Adequate disposal capacity at the least environmental and social costs;

b) Well defined standards and regulations for disposal (e.g. shallow-land burial: site selection, operation, and long-term care); and

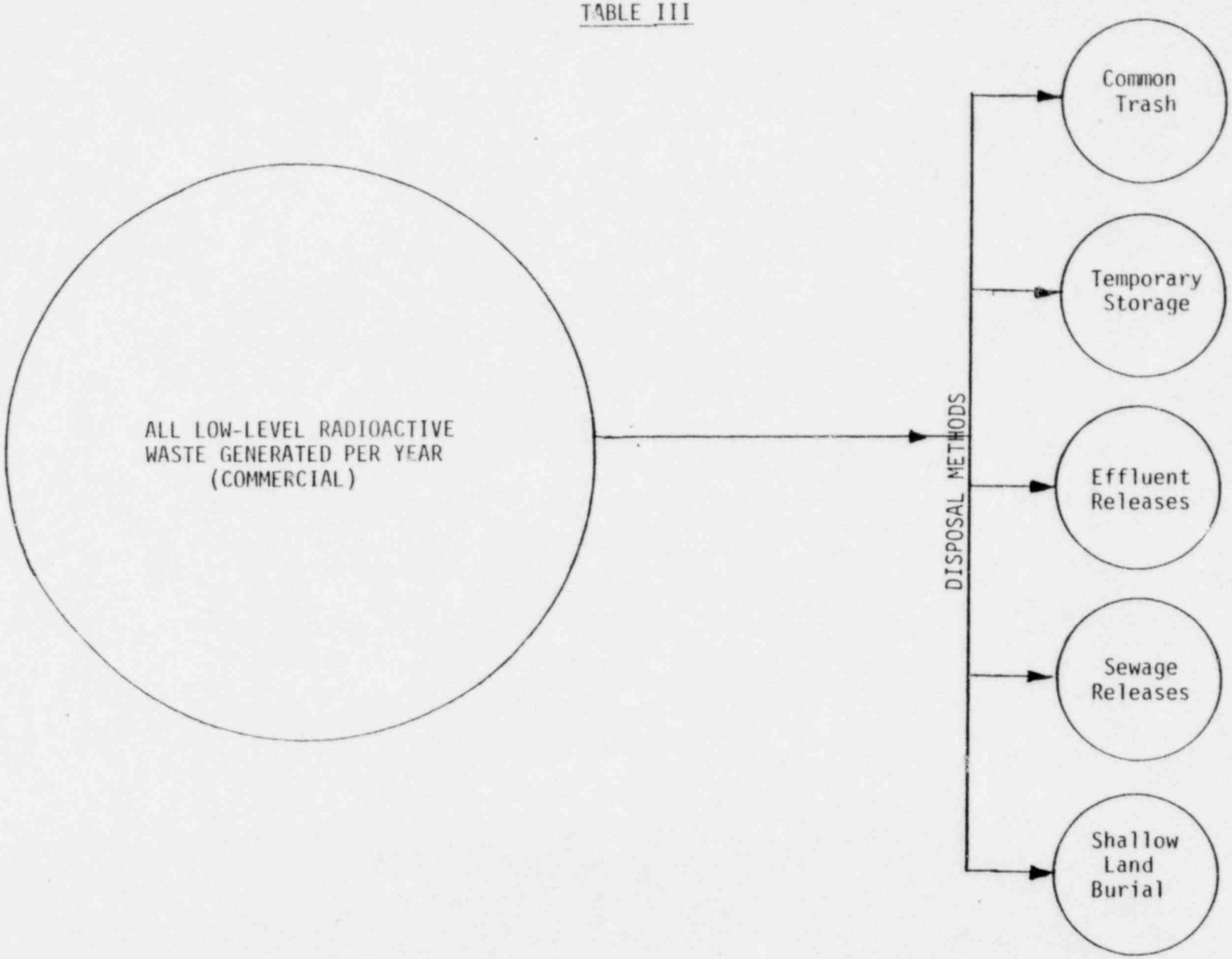
c) Capability of those governmental agencies having responsibility to implement the program.

The first stage in dealing with the development of a low-level radioactive waste management program is a determination of the quantity of waste generated, and where it is generated. The second stage is to determine how it is disposed of: sewage disposal, effluent disposal, decay disposal, or shallow-land burial disposal (Table III). And finally, the third stage is to project the anticipated shallow-land disposal capacity required on a national, regional, and state-by-state basis.

In the face of rapidly changing technological, economic, and political requirements, there has been a common and understandable tendency to concentrate on step three and disposal capacity for burial sites. This tendency has increased with the development of both technical and administrative uncertainties surrounding the number of available sites.

The operational lifetime of each site depends upon the rate at which waste is received, site size, land availability for site expansion,

TABLE III



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operational practices, and institutional considerations. Fundamental to exercising positive control over the lifetime, and timing and location of disposal sites, is a projection of needed waste disposal capacity on a national and regional basis.

A number of "Selective" (addressing either the fuel cycle or non-fuel cycle waste stream individually) and "Comprehensive" (addressing a combination of both the fuel cycle and non-fuel cycle waste streams) forecasts have been developed. They vary considerably as to volume of wastes expected and basic assumptions used. Further. they differ regarding the types and forms of wastes expected, assumptions regarding waste treatment systems to be used at various facilities, and the sources generating waste (i.e. power levels of reactors).

3.1 Selective Projections

Most low-level radioactive wastes are produced, as byproducts of the various phases and fueling requirements, in the operation of commercial nuclear power reactors. The fuel cycle waste stream has been the subject of much research and scrutiny by various researches. Estimates of waste generated has been primarily focused on high-level waste, with cursory attention on low-level waste. These "subset" investigations for low-level waste are generally based on "guestimates". Only one study was located that approached the subject in a systematic manner, with low-level waste as the main topic, and addressed site capacity forecasting needs:

Atomic Industrial Forum (AIF)
A Survey and Evaluation of Handling and Disposing of Solid Low-Level Nuclear Fuel Cycle Wastes
October 1976 (Appendix A)

The AIF study based its forecasting conclusions on a combination of design and operating data, and a survey.

Although less well known, a significant portion of the low-level radioactive wastes disposed of in this country are products of the non-fuel cycle waste stream. The source of these wastes are the possessors of some 16,000+ licenses. These licenses are a heterogeneous mixture of individuals and institutions in the commercial institutional, medical, and industrial sector.

Albeit even with the large number of licenses, there has been almost no research regarding this type of waste. Just one two-part investigation was located that assessed the subject:

T.J. Beck, et al.
Institutional Radioactive Wastes - 1977: Final Report
Radiation Safety Office
University of Maryland at Baltimore
Prepared for U.S. Nuclear Regulatory Commission
Report: NUREG/CR-1137
October 1979 (Appendix B)

The study conclusions and projections were formulated by using survey data, manipulated by accepted methodologies, in combination with characteristic correlation and behavior analysis. Results were calibrated against a comprehensive study result performed by the Environmental

Protection Agency (Appendix D).

3.2 Comprehensive Projections

Comprehensive projections addressing both the fuel cycle and non-fuel cycle waste streams did not appear until 12 years after the first commercial low-level radioactive waste site opened in 1962. Since that time only three studies have attempted to provide an overall assessment:

- The Teknekron Study sponsored by the Nuclear Regulatory Commission (Appendix C)[1]
- The Holcomb Studies sponsored by the Environmental Protection Agency (Apendix D)[2,3,4]
- The NUS Study sponsored by the Department of Energy (Appendix E)[5]

The Teknekron Study was aborted before completion because of contract problems. A task report was completed outlining the computer model characteristics available for use in analysis of the fuel cycle and non-fuel cycle waste streams.

The EPA studies began in 1974 and were updated in 1978 and 1980. The two updates were extensions of the original 1974 study based on acquiring additional data on waste received at the sites.

The DOE studies by NUS were measurement studies with no projections until the agency reevaluated the information for the Low-Level Radioactive Waste Policy Act Report[6] in response to the Public Law 96-573. This report included a projection based on the measurement study's conclusions.

3.3 Model Evaluations

An examination of forecasting approaches used in making comprehensive projections for low-level radioactive waste burial site capacity, reveals that the trend is excusively an empirical relationship or "top down" path. The general thrust of the initial modeling effort is made by first determining the total low-level radioactive waste quantities buried at each site, and then segregating these figures into fuel cycle and non-fuel cycle waste stream categories. The primary data source is extrapolated historical information from shipping/burial site inventories, obtained from site operators or State Radiological Health Offices (through contract agreement). For the fuel cycle waste stream, secondary data is acquired from design and operating calculations, survey data, and electrical energy forecast demands. Due to the extreme lack of availability of secondary sources for the non-fuel cycle waste stream, little if any additional information is acquired.

Once the data is gathered, the modeler organizes and tabulates it for use in the forecasting model by first creating a measurement model. To analyze the data, extrapolation methodology techniques are then applied.

With this method, the basic strategy is to find time series data that are representative of the event to be forecast. The assumption made is that future events will conform to these data. Sometimes the choice of data is obvious and other times the data are not so obvious.

Modelers obtain data from one or more of the following sources:

1) Historical Data: data for an event that is of interest accumulated over a period of time. Accuracy is affected by two major conditions: a) accuracy of the data, and b) the extent to which underlying conditions will change in the future. Measurement error has a large impact on projections. This measurement error is of major importance because real world data are often inaccurate.

2) Analogus Data: data that are from similar situation calculations used as primary data or factored into calculations.

3) Laboratory Simulated Data: data calculations obtained from simulated testing in a laboratory environment.

4) Field Simulated Data: data calculations obtained from field testing.

Historical data are useful for extrapolation if they are timely and accurate, and if the underlying process is expected to be stable in the future. If historical data are not available, an analogous situation may be constructed for analysis. If analogous data are not feasible, simulated data from laboratory or field tests are appropriate for estimating current status or making projections - simulated data however may be seriously influenced by bias and therefore non-representative of actual situations.

Two major approaches are used in calibrating the data. The first approach is exponential smoothing. This smoothing draws upon the philosophy of decomposition whereby time series data are assumed to be made up of some basic components such as average, trend, periodicity, and error. Weight is placed on the most recent data. Weight on earlier periods drops off exponentially, so that the older the data, the less influence. Users of exponential smoothing often invest much time and energy in selecting the optimal smoothing factors.

The second approach is to run a regression using time as the independent variable. This method weights all the historical data equally and provides estimates of both current status and trend. The forecasting accuracy of regression against time is generally accepted to be slightly inferior to that of exponential smoothing.

Current burial site capacity modeling trends indicate modelers use an amalgamated forecast, for calculating projections based on extrapolation methodology and data source techniques to compute the calculations. To arrive at a projection for fuel cycle wastes to the year 2000, annual waste volumes are plotted on a linear scale vs power generating capacity (in MW(e)) for a specified date-span increment. Using the least-squares method of regression analysis, the calculations and plots are then projected to give a forecast. To enhance the usability of the forecast, exponential smoothing is applied for variables that include operating calculations from field data, design calculations from laboratory data, and electrical energy forecast demands. Causal relationships have also been hypothesized using license application data and U.S. population figures (NUS Study). Moreover, calibrations reflecting national, regional, or state profiles are often included for analysis on site capacity.

Non-fuel cycle waste values are calculated on the assumption they will remain relatively constant through the year 2000. No smoothing is applied when extending calculations over time.

3.4 Model Limitations

Comparison of forecasting models with the available "real world" data, disclosed ample evidence of the fundamental weaknesses and vulnerabilities inherent in the methods used, the reference system theory, and the low-level radioactive waste data. With the exception of the mathematical modeling techniques, flaws can be attributed, in part to the historical development of waste forecasting, and to a greater extent, the complexity of the behavior of the reference system.

From a historical standpoint, forecasts concentrated on wastes to be generated from the fuel cycle waste stream. They were originally developed from design and minimal operating data (AIF Study). When the waste sites began to exhibit technological problems and close down, environmental concerns prompted a modeling shift to impacts of waste quantity and activity buried at the sites (EPA Studies). Concentration still remained on the fuel cycle waste stream, in the belief that it was the more hazardous threat, and greater amounts would be generated (based on projected electric power demands). Non-fuel cycle waste was assumed to have minimal immediate or long-term impacts.

With the closing of three of the six commercial burial sites and the development of transportation problems (packaging and contamination), a third modeling shift prompted focus on the quantities and activities of wastes shipped to the sites. Emphasis was also placed on state activities (NUS Study). Periodic embargos by the states housing the three open sites, and the national focus on the shortage of low-level radioactive waste burial capacity, prompted a fourth shift focusing on the quantity,activity, and location of generated waste (DOE response to the Low-Level Radioactive Waste Policy Act). Continuing change in world energy resource allocation policies, the Three Mile Island (TMI) accident, chemical hazardous waste concerns, and shifts in nuclear power policies, added emphasis to this directional shift.

The first two modeling efforts concentrated on Descriptive Forecasting Models for the purpose of characterizing the important features of the existing burial sites, and to help in understanding the problems associated with them. They were primarily developed to aid in experimentation and research.

The third modeling effort was not a Forecasting Model, but a Measurement Model. It attempted to tabulate and quantify the waste buried at the commercial sites.

The fourth and latest modeling effort however was a major change in conceptual direction and effort. It focused on both a Prescriptive Forecasting Model prescribing a solution to the problems, and a Normative Forecasting Model identifying feasible and desirable regional configurations of the problems, to serve as a goal or standard.

The complexity of the waste generation processes has great influence on the availability of data. Consequently to accommodate for the lack of data, modelers have concentrated on optimization and simplification, in an effort to offer a rational approach. They make essential distinctions by specifying desired relationships between manipulable means and obtainable objectives. Their strength lies in the ability to make a little knowledge go a long way, by combining an understanding of the constraints of the situation with the ability to explore an environment constructively. Their weakness lies in the tendency to make quite arbitrary decisions, on the major factors and assumptions that support or will not support their modeling method choices. Moreover, in attempting to deal with these difficulties, modelers themselves act on the environment, thus becoming part of the problem with which they are attempting to cope.

A closer look at the technical complexity of the reference system readily gives rise to an understanding of the modeling problems encountered by modelers. For example, focus has been on wastes generated from nuclear power reactors rather than other entities in the nuclear industry, but not all contributions from the fuel cycle waste stream are included. Generally wastes from such sources as uranium conversion, fuel fabrication facilities, and reprocessing are omitted. Design calculations are also simplified as well as other causal variable factors influencing production, e.g. load factors, startup difficulties, age, etc. In addition, estimated or simplified data can be identified as having been used in design improvements, better performance of waste systems, solidification operations, incineration operations, packaging techniques, or burial of shield material. In many cases the data required to factor in impacts of a causal variable are unavailable. Changes in regulations or operating restrictions may result in a significant impact that cannot be measured or factored into a forecast model (i.e. solidification of liquid waste).

In addition, regulation jurisdiction and agency purpose play an extremely important role in modeling. The Nuclear Regulatory Commission has licensing jurisdiction, and therefore the ability to require licensees to report data, either directly or indirectly through the Agreement State Program. The Department of Energy has research and development responsibility. The split personality of data functions can hamper acquisition and influence modeling techniques.

Modeling techniques are also vulnerable to the influences and limitations of other forecasts that have an impact on waste generation. Most notable are energy demand forecasts. They are based on many factors, including consideration of trends in economic conditions, population growth, and industrial production. Present conditions for projecting demands are less than ideal. Previously established trends-of-growth indicators have been undermined by changes in world energy resource allocation policies, a general decline in the demand for energy, and instability in the financial and capital structure. Projection of nuclear power growth beyond the point of present commitments is difficult because of theses uncertainties. Estimates of energy demand therefore can cover a wide range of conclusions.

3.5 Model Applications

Models are highly dependent on their manner of use and understanding of the user. Therefore, both builders and users of models must be careful to be very explicit about the assumptions and the inherent limitations of the models. Failure to do so may result in a "meaningless forecasting stastic" that is nothing more than an advocate in technological guise, used to legitimize assumptions that do not actually apply (particularly if a descriptive model projection or measurement statistic is applies to a prescriptive or normative projection problem.

It must be kept in mind that models are a technology based more on personal ingenuity and the way things appear to be, than on scientific discovery and objective truth. They permit an efficient means of testing the effects of various changes in assumptions and should be used as a framework to achieve reasonableness and consistency. Systematic modeling can help sort out the implications of "what-if" classes of surprises, and thus can help to understand the extent of uncertainty. They portray the possible, not necessarily the probable, and certainly not the inevitable. No model exists which allows development of precise forecast projections.

Failure to apply forecast projections, within the boundaries of their limitations, will convert theory into action, increasing the uncertainty surrounding a problem rather than reducing it. Substantial evidence can be identified to support a trend in this direction, for use of the projections from EPA and DOE modeling forecasts.

3.5.1. EPA Studies

EPA studies were developed out of environmental concerns for the [illegible] of characterizing important features of the existing burial sites, and to help in understanding the problems associated with them. The AIF study was the only other effort to look at the problem.

Concentration by EPA was on a Descriptive Forecasting Model with emphasis on the fuel cycle waste stream. Given that nearly all fuel cycle wastes, with the exception of effluents (less than 1%) is shipped to a shallow-land burial site for disposal, it is the most hazardous, and large increases in the quantity were expected, the forecast model reference system was based on the theory that all low-level radioactive waste generated will be disposed of in shallow-land burial sites.

When the modeler turned to the non-fuel cycle waste stream for inclusion in the model, reference system calculations were based on the same theory due to the lack of quantitative data. Tabulations were confined to limited historical extrapolation of burial site records, and "guestimates" for percentages of waste attributed to medical, industrial, and institutional sources (made by state radiological health offices in the states where the sites are located).

With a few isolated exceptions, references to EPA's fuel cycle waste stream projections are almost never used for any purpose other than research notations. However that is not the case for non-fuel cycle waste stream projections, particularly the percentages attributed to medical, industrial, and institutional sources.

A fair number of references can be found within the public domain referring to the source percentages, giving the impression that they are based on a scientific finding. The most serious and far reaching use of the percentage data however is in the University of Maryland Study, Institutional Radioactive Wastes; the NUS State-By-State Measurement Model Study; and subsequently incorporated in the DOE response to the Low-Level Radioactive Waste Policy Act (based on the NUS Model). All three studies factored the EPA non-fuel cycle waste stream percentages into their assessments. Use of the figures for any reason is highly questionable because:

1) The figures are subjective "questimates" obtained from state radiological health offices in the states where the sites are located, and

2) The reference system or universe theory used in the model was overly simplistic of the real world, due to the lack of available knowledge about the reference system's causal variables (Figure 4).

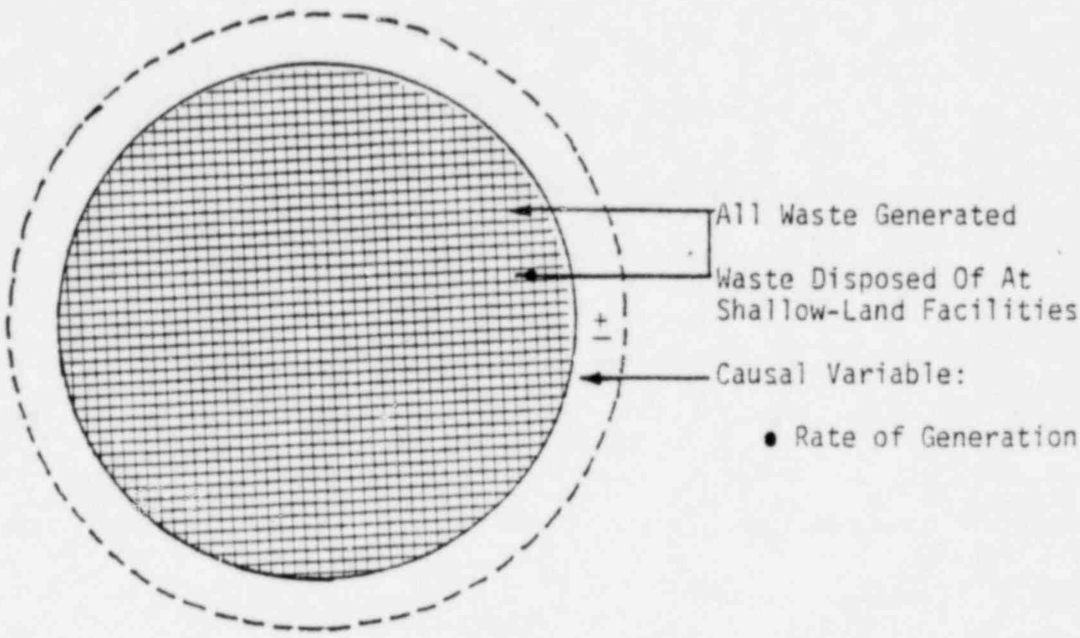
3.5.2 NUS Study/DOE Study

The NUS Measurement Model was developed from concerns regarding packaging, transportation, and the growing interest with commercial shallow-land burial sites. The study used the same data records (different source) as the EPA models. The modeler however factored in a number of subjective hypotheses among which included exponential smoothing of U.S. population figures and licensee data. Its basic purpose was to measure the amount of commercial low-level radioactive waste shipped for burial on a state-by-state basis.

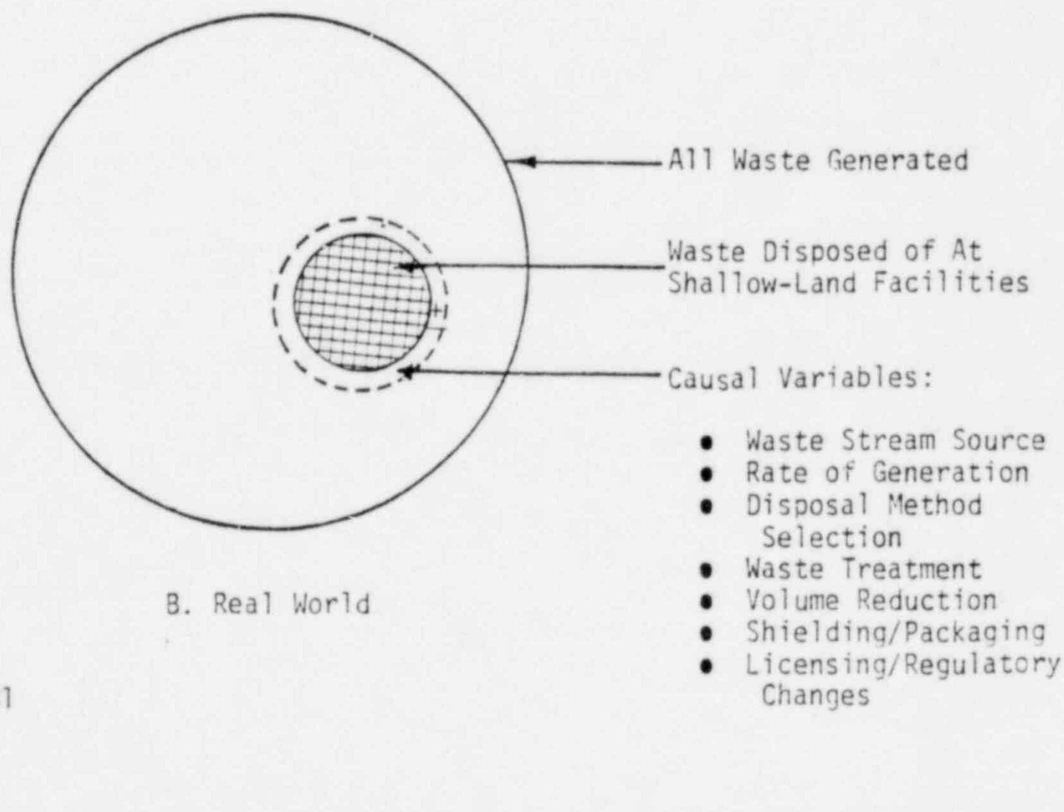
With the passage of the Low-Level Radioactive Policy Act in December 1980, the Department of Energy was mandated to assist the states in assuming responsibility for disposal capacity needed, for present and future low-level radioactive waste on a regional basis, and was request in addition, to include an inventory of the types and quantities of waste. DOE complied with the Low-Level Radioactive Waste Policy Act Report: Response to Public Law 96-573. The Forecasting Model in this report was based on the NUS State-By-State Assessment of Low-Level Radioactive Waste Shipped

Figure 4

Commercial Low-Level Radioactive Waste
Genertaion/Burial Relationships



A. Forecast Model Steady-State Assumptions



B. Real World

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to Commercial Burial Grounds,[6] quantitative data and extrapolation methods. It was to serve the purpose of both a Prescriptive Forecasting Model to prescribe a solution to the problem, and a Normative Forecasting Model to identify a feasible and desirable configuration of the reference system to serve as a goal or standard.

The problems to be solved were carefully and precisely defined by Congress:

1) How much low-level radioactive waste is presently generated (quantity and activity)?

2) How much low-level radioactive waste is anticipated to be generated in the future (quantity and activity)?

3) How much low-level radioactive waste generated is shipped for burial in commercial shallow-land burial sites?

4) How much low-level radioactive waste is anticipated to be shipped for burial in commercial shallow-land burial sites?

5) Based on the quantity of expected low-level radioactive waste generation, what is the regional distribution?

Albeit unintentionally, Congress was asking for an "Unknowable Statistic". There are no aggregate data available on waste generation, only waste shipped for burial. All fuel cycle and non-fuel cycle waste stream low-level radioactive waste generated is not buried in commercial sites.

To gather and tabulate the data required, the Nuclear Regulatory Commission would need to require statistical reporting, by its licensees, either directly or indirectly through the Agreement State Program. At the present time regulations only require licensees to maintain records for inspection purposes. Licensees are not required to submit periodic waste generation data.

To meet the Congressional mandate, the Department of Energy turned to the

NUS Measurement Assessment of low-level radioactive waste shipped to commercial burial grounds for quantitative data. Using an extrapolation methodology, DOE prepared forecast projections for the response to P.L. 96-573. The accuracy of this forecast is seriously questionable because it:

1) Misrepresents the relationship of the reference system to the forecasting problem.
2) Factors in U.S. population figures and licensee statistics as a causal factor based on the opinion of the modeler.
3) Oversimplifies anticipated changes in the reference system.
4) Oversimplifies the complexity of the behavior of the reference system.

The understandability and utility of the projections moreover are open to great discussion.

Because of the questionable accuracy of the DOE projections, a number of states have prepared independent evaluations. Of those currently available, the State of Kentucky found that NUS figures indicated an over assessment of 55% waste attributed to be generated in that state. Further review of the large discrepancy found that of the 3036.9 cubic feet over assessment, 1619 cubic feet did not even travel on Kentucky highways.[7] The State of Texas also found that they generated 40% lower than NUS figures reflected, and the State of Minnesota 60% lower than reflected.[8]

Potential state compact groups are just beginning to encounter the data problems. A recent example is the Coalition of Northeastern Governors' Low-Level Radioactive Waste Policy Working Group (CONEG). This group has analyzed the available data studies and found a dilemma in trying to reconcile differences to make policy decisions.[9] Six of the nine states are non-Agreement States and have no jurisdictional ability to obtain licensee data for clarifying differences.

3.6 References

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2. O'Connell, M.F. and W.F. Holcomb, "A Summary of Low-Level Radioactive Wastes Buried at Commercial Sites Between 1962-1973, with Projections to the Year 2000", Radiation Data Reports, 15(11), December 1974.

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8. State of Texas. Texas Energy and Natural Resources Advisory Council, Advisory Committee on Nuclear Energy. Report on Low-Level Radioactive Waste Disposal, September 1980.

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4.0 Common Data Bank

Accelerating demands for low-level radioactive waste generating data and the lack of confidence with the currently available data have made it urgently essential, that positive efforts toward the development of improved assessment and forecasting methodologies, supported by an accurate, comprehensive data bank, be promoted. Whereas the waste management regulations will set forth performance criteria to be met by licensed facilities, the licensing methodologies and data bases will provide technical staff with the necessary analytical and programmatic tools to evaluate proposed systems against the standards. Such a data bank by necessity must provide directly acquired licensee data (generator), under uniform reporting conditions, to a controlled responsibility center.

The preparation of a data bank will likewise aid in providing information to help states in making waste management decisions, and individuals in all phases of the industry, understand the impact of waste generation on current waste management techniques, and for evaluation of alternatives to current waste management practices. For example, states and burial site contractors should be cognizant of the actual volumes and types of wastes expected to be generated within individual state borders and from what sources. Designers and engineers need pertinent information to provide adequate waste processing and handling systems, and radiologists need information to determine radiation exposure from handling waste.

4.1 Centralized Data Bank

The need for a centralized data bank approach to handling low-level radioactive waste information is a natural evolution of the maturing of the nuclear industry. An effective method of cataloging and assembling data bank information is to identify, classify, and organize the information into individual computerized data bases. Collectively the data bases would provide a low-level radioactive waste inventory data bank covering:

a) Waste Generation Inventories: type, source (fuel cycle, non-fuel cycle); amounts (curies, volumes, mass); characteristics (physical form, chemical form, radionuclide concentration, biological context); properties (leach, thermal, structural, radiation, biodegradation reactivity); treatment; reduction;

b) Waste Disposal Inventories: shallow-land burial, backyard burial, sewage, effluents, common trash;

c) Transportation Inventories.

Such data storage and retrieval systems would have the capability of providing a meaningful, consistent, quantifiable inventory or operational data to permit enhanced:

a) Regulation and licensing Assessment

- An accurate inventory of radionuclides and other related toxic material generated (i.e. impact to disposal).
- Identification of major generators of high specific activity waste or radionuclides of concern (assess that wastes are placed in a form and disposed of by a method which assures adequate containment).
- Identification of generators of large volumes of waste.
- Identification of waste reduction practices, incineration, compaction, other (i.e. impact to shallow-land burial site capacity).

- Identification of waste generators or shippers who consistently violate regulations or disposal site license conditions (i.e. increased inspection and enforcement actions).

b) Mathematical Modeling and Analytical Assessment

- Projections of waste generated for:
    - shallow-land burial
    - sewage disposal
    - effluent release
    - backyard burial
    - common trash
- Use trends of a nuclide category: curie quantity, volumes, weight, form, decay, treatment, disposal, etc.

4.2 Responsibility Center

Fundamental to the success of a data bank process is the need to centrally organize the data required, so that there will be an orderly flow of information on a continuing basis. A single, centralized responsibility center is the ideal mode of operation, to effectively maintain the data bank and to provide information in a timely and expeditious manner. By establishing a centralized responsibility center where all data is housed, the data base collection and reporting would be consolidated to:

a) Avoid duplication of effort.

b) Guarantee data integrity preservation.

c) Consistent data.

d) That undue burdens are not placed on the licensee or other data sources.

Present demand for radioactive waste data indicates that a responsibility center would have a ready clientele in federal government agencies, state regulatory bodies and state government agencies, burial ground operators, equipment developers, private industry, and educational institutions. The benefits of a centralized data bank are numerous and far reaching, thus justifying the cost and effort required for its establishment.

4.3 Current Improved Data Collection Effort

Evolving out of the Nuclear Regulatory Commission's regulatory development program, and in response to the needs and requests expressed by Congress, the public, the states, the industry, and other federal agencies, are a number of efforts to move in the direction of improved data collection. One effort now in progress is the development of contractual agreements to obtain copies of low-level radioactive waste disposal records directly from the site operators (i.e. Chem-Nuclear Corporation for the Barnwell, South Carolina site) for the 1980, 1981, and 1982 calendar year. The records will be analyzed and organized into data bases.

A second and more far reaching effort is the promulgation of rules and regulations governing licensing for land disposal of low-level radioactive waste (Proposed 10 CFR 61) directly establishing requirements for an improved manifest tracking system (10 CFR 20.311 Proposed) that addresses the needs for more complete information on the classification and characteristics of wastes, for improved accountability of wastes, and to provide a better data base of wastes shipped for shallow-land burial.

4.4 Data Collection Innovation

Given the legislative mandates and constraints brought to bear on any efforts to collect low-level radioactive waste generating data from licensees, it would be prudent for the Nuclear Regulatory Commission and other federal agencies to investigate innovative alternatives to the problem. One such innovation the NRC could explore for example is the record keeping and reporting requirements, for the United States Population Census taken every 10 years. The census is designed such that every household is required to supply basic information determined to be necessary for the statistical abstract data bases. Selected at random are a number of additional households designed to supply answers for further survey inquiries.

The NRC has the regulatory and statutory authority to develop a similar system derived from generating licensees through recordkeeping and reporting requirements. The data acquired would provide a technical and statistical data information bank on low-level radioactive waste generation, while at the same time minimizing the burden to the licensees, if it were required at 3-year or 5-year intervals. Selected licensees (i.e. large volume generators) could be required to provide information at shorter intervals.

The Paperwork Reduction Act of 1980 (P.L. 95-511) gives the NRC the administrative statutory authority to implement such an innovation. A primary emphasis of the Act is to eliminate duplication on the part of both the federal government and the private sector as well as the states. The

Office of Management and Budget (OMB) has the responsibility for establishing a Federal Locator System (FILS) as the authoritative register for all information collection requirements. It is to include:

- Directory of Information Sources
- Data Element Dictionary
- Information Referral Service

If it is found that two or more agencies need identical or similar data to carry out their jurisdictional functions or statutory mandates, a central collection agency will be designated as the appropriate entity to collect the data. Selection of the collection center responsibility falls on the shoulders of the agencies involved. If an agreement cannot be reached, OMB has the authority to make the determination. Each agency is responsible for reviewing and ensuring its information systems do not overlap each other, or duplicate systems in other agencies. In addition, each agency is also required to formulate plans for tabulating the information it collects or is available to it, in a manner which will enhance its usefulness to other agencies and the public.

There presently is a duplication of information needs or requirements for the Nuclear Regulatory Commission, the Department of Energy, the Environmental Protection Agency, and the Department of Transportation for low-level radioactive waste data. To satisfy these needs in a meaningful and informative way, generating data obtained directly from the licensee is required. Transportation manifests, burial site records, or state radiological health department records, are not acceptable substitutes for certain types of data needs. Only the Nuclear Regulatory Commission directly, or through the Agreement States Program, has reporting requirement jurisdiction for the licensees. Thus efforts towards any innovation (i.e. periodic census) must be initiated with the NRC.

5.0 Evaluations and Conclusions

Although shallow-land waste burial site demands have more visibly focused on the need for accurate data, the ever increasing use of nuclear energy and radioactive isotopes in medical and industrial application, have also demonstrated the need for a timely access to the most current information about radioactive waste management activities. To fill this accelerating data demand, there has been a common and understandable tendency to concentrate on readily available shipping and shallow-land burial site data (i.e. state radiological office records, disposal site inventories, and shipping manifests), to provide both burial site impact projections and generation forecasts. Real time demands and statutory requirements have forced empirical relationships to take precedent over a systematic scientific methodology, and to establish the information data bases required for assessing low-level radioactive waste generation and its impacts on waste management activities.

A tacit finding of this study is that sufficient quantitative data are not currently available to support valid conclusions about the quantities or activity of low-level radioactive waste now generated or that may be generated in the future. Modeling efforts to construct a statistical basis for an examination of scientific relationships, cross-section trend questions, or ultimately site capacity impacts, are highly subjective and difficult to evaluate. All projection conclusions based on such data are open to serious question. Any attempt to utilize the information for policy decision is analogous to tap dancing with flippers. Moreover, by continuing to make do with inadequate information, statistical problems thus far encountered will be compounded and policy management activities further handicapped.

Given this environment, the issues then are, what is the path of prudence, and what should be expected from institutions in light of this uncertainty.

5.1 Impact to State Role

Congress, through the passage of the Low-Level Radioactive Waste Policy Act of 1980, formally established disposal capacity as a state responsibility either individually or regionally. To meet the responsibility of this mandate, states were confronted with three choices:

1) Developing a state site within the State borders, or
2) Joining an interstate compact with other states in the region, or
3) Stopping the generation of low-level radioactive waste within its borders.

The third option is the least desirable one, and more or less out of the question or unrealistic. Regardless of general opinions on nuclear power, significant quantities of low-level waste are generated in all 50 states by hospitals and clinics in therapeutic and diagnostic techniques, universities in research and teaching, and various kinds of industries. For a state to stop producing these wastes, it would have to forego the benefits arising from medical, research, and industrial uses. In the 24 states possessing nuclear power reactors, it would be shutting down operating electrical power generation.

Each state therefore must make a feasibility determination regarding option one, operating a single-state facility, or option two, entering into a compact or regional facility arrangement. To make such a determination will require a major effort and commitment. There is no model plan available for establishing a new low-level radioactive waste facility, and existing sites were proposed and developed in an environmental, institutional, political, social, economic, and technical arena greatly differing from that which exists today.

Moreover, the quest to establish additional disposal capacity has come at a time of heightened public concern about the construction of facilities designed to handle or process any wastes that could be termed hazardous. This is further intensified by the Reagan Administration's budget cuts, and the massive impacts they are having on the state budgets and their ability to allocate priorities to increasingly diminishing resources. An error in choice of option (single-state or regional compact) could have disastrous results that are irreversible and long lasting. Therefore, the final decision must be carefully reviewed and considered before a final choice is made.

The first stage in assessing the current state disposal requirement is to establish:

- Current quantities of waste generated and who the generators are;
- Anticipated quantities of waste to be generated and potential generators;

- Radionuclide content and waste types;
- Packaging and shielding requirements;
- Interim storage capabilities;
- Waste reduction and processing processes.

The next step is to address specific issues impacting administration, organization, and resources regarding the state's environmental, institutional, political, social, economic, and technological concerns and responsibilities. The final stage is to make an option choice.

Fundamental to this whole process is knowing How much? Who? and Where? The only currently available data are burial site and transportation site records found in the forecasting studies. They are not suitable to support the option decisions of a state, and all attempts to do so may have disastrous results. Given the nature of nuclear technology, state expertise in such matters, and state tendencies to defer to federal expertise, there is a serious potential for a trend in this direction.

5.2 Impact to Commission Role

Congress, by statutory mandate, declared that the Nuclear Regulatory Commission is responsible for the protection of the public health and safety, and the environment in regard to the possession and use of radioactive materials. The Commission exercises its low-level radioactive waste management responsibilities through the regulation and licensing process either directly or indirectly through the Agreement State Program. The Low-Level Radioactive Waste Policy Act of 1980 has not pre-empted or diminished that responsibility, nor have efforts to enact regulatory reforms. Congress has on a number of occasions re-affirmed its support for "prompt and efficient" issuance of regulations for hazardous chemical wastes and radioactive wastes. Burdens to the licensee are not to displace health and safety issues.[1]

Increased responsibility for both the states and the Commission prompted the undertaking of a number of studies looking at effective, radioactive waste management roles. Of notable mention is the General Accounting Office (GAO) report issued in March 1980.[2] It concluded that effective waste management is the development of policies and practices used in nuclear science and technology for the control, measurement, handling, and processing of nuclear waste materials or waste material contaminated with radioactivity. Measurement includes the analytical and statistical methods required to account for the amounts of radioactive waste generated, handled, stored, or disposed of.

If further determined that the Commission and the states knew who the shippers of low-level radioactive waste are, but not the generators, or:

- The amounts and types of waste currently generated, or
- A realistic estimate of the projected amounts and types of waste expected to be generated.

The General Accounting Office's determination was supported by the NRC's Advisory Committee on Reactor Safeguards (ACRS) in a recent report[3] to the

Chairman addressing the 10 CFR 61 Proposed Rule for Licensing Requirements for Land Disposal of Radioactive Waste. The Committee indicated that the proposed rule "revealed certain deficiencies in data, particularly with respect to the compilation of detailed inventories on the quantities and specific radionuclide concentrations... such data is essential if the NRC staff is to have a clear understanding of current practices, and if they are to be able to ascertain the impact of various regulatory actions, particularly the influence of the establishment of "de minimus"* concentrations for selected radionuclides in specified types of wastes. Such information is also essential in order to assess the impact of various restrictions of the types of wastes acceptable for disposal in a given site".

With a data capability impediment, the Commission's activity arena is "reactionary" rather than "prepared" or "anticipatory". This in turn places the Commission in a vulnerable posture, that gives rise to weak support for, or inability to perform:

- evaluation of licensing regulatory management,

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* In a recent rule change affecting "de minimus" concentrations of hydrogen-3 and carbon-14, the exact volume of waste was unknown, the NRC therefore prepared a cost/benefit statement based on a survey of large waste generating institutions, believed to account for 21% of biological wastes in the U.S., and the estimated volumes of scintillation counting media evidenced on the number of vials estimated to be manufactured per year in the U.S. (10 CFR 20.306).

- assessment of license applications,
- regulatory development justifications,
- waste generation assessments,
- waste projection assessments, and
- determination of adequate additional disposal capacity and location of new shallow-land burial sites.

5.3 Recommended Commission Activity

Embodied in the statutory mandates of the Atomic Energy Act of 1954, the National Environmental Protection Act of 1969, and the recently passed Low-Level Radioactive Waste Policy Act of 1980 is the recognition that there will always be a federal presence in matters that affect radioactive materials. In addition, there is the recognition that states need to take greater responsibility in matters regarding radioactive materials (Agreement State Program and disposal capacity responsibility for low-level waste). Recognition for greater state responsibility however, in no way negates or pre-empts a strong federal presence.

All major shifts in radioactive materials responsibility concerning state/federal relationships, necessitate by their nature, an evolution of new and often innovative roles. Shifts from federal to state levels of responsibility always place a greater burden on the Commission, to recognize the unique transititonal needs of the states and to provide developmental aid.

The necessity for the Commission to take an active role with the transitional needs of the states is more than evident, with the shift in responsibility brought about by the passage of the Low-Level Radioactive Waste Policy Act of 1980. In upholding the framework of that Act, a prudent role for the Commission is to support states in planning for low-level radioactive waste management and in implementing those plans through a regulation and licensing process.

Because jurisdictional regulatory responsibility for maintaining waste management licensing records lies with the Nuclear Regulatory Commission, a key support function germane to that role is to provide an accurate census of waste generation, to aid in establishing a basis for sound waste management planning for both the states and the Commission. The following recommendations are set forth in support of carrying out such a support function:

1) Build the Commission's long-term capability through a series of analytical and technical data bank building activities.

   a. Sensitivity Assessment Activities:

      - Determine the current automated reporting capabilities of material and facility licensees.
      - Determine the current automated reporting capabilities of state radiological health offices in Agreement and Non-Agreement States.
      - Determine the census reporting impact to licensees generating large volumes or large amounts of radioactivity for the fuel and non-fuel cycle waste streams.
      - Determine the census reporting impact to licensees generating small volumes or small amounts of radioactivity for the fuel cycle and non-fuel cycle waste streams.

b. Census Activities:

- Acquire a low-level radioactive waste census of all material and facility licensee generation data to establish a "Base Year" Census.
- Acquire a low-level radioactive waste census of large generator data (volume and activity) to establish a "Yearly" Census.
- Acquire a low-level radioactive waste census of all material and facility licensee generation data every three (or five) years, to establish a series of time periods for "Cross-Study" Census and comparative trend modeling.

2) Establish a Central Collection Center responsibility for the Commission with inter-agency and intra-agency participation and support.

a. Establish common data base needs for administrative and technical functions that include:

- Waste Generation Inventories: type, source (fuel cycle, non-fuel cycle), amounts (curies, volumes, mass), characteristics (physical form, chemical form, radionuclide concentration, biological context), properties (leach, thermal, structural, radiation, biodegration, reactivity), treatment/reduction;
- Waste Disposal Inventories: shallow-land burial, backyard burial, sewage, effluents, common trash;
- Transportation Inventories.

b. Establish a basis for shared inter-agency financial responsibility.

3) Design (in incremental stages) an automated Common Data Bank System based on inter-agency and intra-agency requirements.

5.4 References

1. Danielson, George, Opening remarks before the House Judiciary Committee for mark up of Bill H.R.746 on Regularory Reform, October 16, 1981.

2. Comptroller General of the United States, U.S. General Accounting Office. Report to the Congress of the United States: The Problem of Disposing of Nuclear Low-Level Waste: Where Do We Go From Here? Report: EMD-80-68. March 31, 1980.

3. Letter from J. Carson Mark, Chairman, ACRS, to Chairman Nunzio J. Palladino, Chairman, Nuclear Regulatory Commission, September 16, 1981.

APPENDIX A

A Survey and Evaluation of Handling and Disposing of Solid Low-Level Nuclear Fuel Cycle Wastes

The NUS Corporation was commissioned in 1975 by the Atomic Industrial Forum (AIF) to perform a study to identify the types and quantities of solid radioactive wastes for each portion of the nuclear fuel cycle. Information for the study was based on actual operational data and facility designs. The sources, types, and amounts of solid radioactive waste were identified, and the cumulative volume was projected to the year 2000.

To obtain the data (Table A-I through A-VII) needed for this study, questionnaires were developed and sent to eight fuel fabrication facilities, thirty-nine reactor sites, and six commercial waste disposal sites. The questionnaires were designed to document information on radioactive waste system equipment and operation, methods of packaging, personnel exposures associated with radioactive waste processing and handling, annual waste volume generation, and waste disposal methods. In addition, visits were made to several power reactors, two of the six burial sites, and one of the interim transuranic storage areas, to review present methods used to process and handle waste. Five architect-engineering firms were interviewed on designs for present and future radioactive waste systems. Where data was not made available by the burial facilities, federal and state regulatory agencies with authority over those sites were contacted. Additional information was obtained from government reports, published

TABLE A-I*

SUMMARY OF LWR RADWASTE VOLUMES FROM SEMIANNUAL REPORTS

Plant or Site	Annual Volumes of Radwaste Shipped, Cubic Feet							
	1968	1969	1970	1971	1972	1973	1974	1975[a]
1	7,800	3,400	9,600	15,000	20,000	17,800	18,500	
2	3,800	4,800	3,800	4,500	7,800	4,300	(9,000)[b]	
3	500	700	1,500	800	3,400	4,000	2,400	2,800
4	1,100	900	900	600	3,300	6,900	15,700	9,900
5	2,500	900	900	1,500	29,000	400	1,400	
6	400	0	1,400	2,400	2,100	3,100	1,800	
7	400	2,900	2,100	3,700	6,700	5,600	7,200	15,500
8	500	600	700	0	900	9,000	1,500	100
Total 1-8	17,000	14,200	21,000	28,500	73,200	51,600	57,500	–
9			7,700	10,900	26,600	29,400	42,700	19,200
10			3,100	12,900	15,100	19,200	15,900	8,000
11			1,800	24,800	12,900	7,000	9,700	
12			13,200	19,700	18,500	40,000	43,000	13,600
Total 9-12			25,800	68,300	73,100	95,600	111,300	–
13				900	2,500	10,300	13,000	4,800
14				6,000	6,600	8,600	29,400	36,100
15				10,900	6,300	7,400	9,400	4,800
16				2,700	6,800	10,400	4,700	5,600
17				2,100	36,900	36,200	40,200	22,500
Total 13-17				23,500	59,100	72,900	96,700	–
18					17,000	36,200	37,600	13,600
19					300	4,500	13,900	14,000
20					100	8,200	15,900	15,500
21					0	2,400	5,600	6,700
22					5,000	6,600	7,000	
23					5,600	12,900	44,100	18,500
24					2,400	7,700	14,300	3,500
Total 18-24					30,400	78,500	133,400	–
25						9,300	32,100	24,000
26						20,300	58,600	29,000
27						1,600	11,400	12,300
28						1,100	18,000	11,900
Total 25-28						32,300	120,100	–
29							14,100	
30							0	600
31							4,400	
32							11,300	5,200
33							7,100	5,300
34							13,400	5,300
35							4,800	2,300
Total 29-35							55,100	–
Total 1-36	17,000	14,200	46,800	120,300	2[illegible]5,000	330,400	574,100	
Ft^3/Yr/MWe	9.8	7.6	10.8	14.5	17.6	16.7	23.1	33.8

NOTES: (a) Volumes for 1975 include Jan.–June shipments only. On the average, reactor plants ship 40% of their waste during that period.

(b) Volume in parentheses estimated from partial data.

*Source: AIF Study

TABLE A-II*

SUMMARY OF ANNUAL SHIPMENTS OF SOLID WASTE FROM OPERATING REACTORS FROM SEMI ANNUAL REPORT

Annual Shipments and Specific Activity of Solid Waste From Operating Reactors

Plant or Site	1969 No. of Shipments	1969 Specific Activity Ci/Ft³	1970 No. of Shipments	1970 Specific Activity Ci/Ft³	1971 No. of Shipments	1971 Specific Activity Ci/Ft³	1972 No. of Shipments	1972 Specific Activity Ci/Ft³	1973 No. of Shipments	1973 Specific Activity Ci/Ft³	1974 No. of Shipments	1974 Specific Activity Ci/Ft³	1975[a] No. of Shipments	1975[a] Specific Activity Ci/Ft³
1	3	0.080	10	0.003	18	0.0004	22	0.007	15[b]	0.0002				—
2	15	0.034	10	0.002	8	0.001	18	0.0003	11	0.0007	22[b]	0.013	5	—
3	2	0.011	2	0.007	2	0.001		0.074	13	0.015	11	0.016	—	—
4	2	0.010	2	0.007	1	0.004	7	0.048	11	0.047	27	0.004	38	0.075
5	3	0.070	2	15.3	1	0.002	17	0.745	22	30	4	0.068	—	—
6	0	—	2	0.004	2	0.002	3	0.003				0.019	—	—
									—	0.006	5	0.156(R)	—	—
7	1	<0.0001	2	0.0001	3	0.101	4	0.027	2	0.0001	3	0.010	—	—
										0.101		0.130		0.014
8	10	0.017	6	0.153	12	0.074	21	0.716	11	0.613(R)	24	1.176(R)	21	0.55(R)
						0.249(R)		3.18(R)		0.637(F)		0.277(F)		0.0003(T)
						0.234(F)		0.043(F)		0.011(T)		0.007(T)		
						0.002(T)		0.0005(T)				0.656(L)		
9	2	0.0004	1	0.017	0	—	2	—	11	0.005	5	0.319	1	1.11(R)
										0.098		0.037		
10			30	0.0004	18	0.0005	68	0.050	157	4.79(R)	108	2.37(R)	74	0.054
11			3	0.0012	44	0.0156	60	0.0175	66	0.0522	75	0.121		
12			3	0.0025	24	0.5019	51	0.109	29	0.00857	26	0.063		
13			25	0.0007	41	0.0025	43	0.0033	93	0.0373	486	0.063		
14					2	0.0003	5	0.0019	31	0.0034	31	0.066		
												0.7058		
15					28	0.009	41	0.249	65	0.176	—	0.014(R)	—	0.028
16					15	0.156	13	0.014	35	0.053	47	0.262	23	0.481
17					6	0.0013	15	0.031	19	0.176	12	0.454	16	1.098
18					4	<0.0001	72	0.0003	158	0.008	—	0.013	192	0.032
							39	0.003	85	0.270	161	—		
							2	0.0053(R)		0.0100		0.002		
									11	0.074(R)	27	0.110(R)	30	0.0091
										0.046(F)		0.012(F)		
										0.0007(T)		0.0005(T)		
												0.0005(L)		
20							0	—	12	0.0005	22	0.0028	28	0.0033
21							0	—	5	0.0014	14	0.0528	—	0.205
22							13	0.0035	31	0.0036	36	0.0154		
23														
24							—	<0.0001	19	0.0501	68	0.0011	52	0.0310
25							4	0.008	—	0.074	—	0.102	13	0.188
										0.078(R)		0.036(R)		
										0.015(F)		0.027(F)		
										0.057(T)		0.002(T)		
										5.87(L)		3.81(L)		
26									26	0.0034	81	0.007	—	0.057
27									—	<0.0001	—	<0.0001	53	0.0002
28									2	<0.0001	18	0.0009	21	0.0025
29									4	0.0003	41	0.0035	37	0.0038
30											64	0.0057		
31											0	0	1	0.0038
32											7	0.0019		
33											26	0.0064	12	0.0095
34											16	0.0009	14	0.0126
35											28	0.0013	11	0.0152
36											10	0.0016	5	0.0007

Notes: a. First six months of 1975 reported
b. Data reported for six month period only

Legend: (R) denotes demineralizer resin
(F) denotes filters or filter demineralizer sludge
(T) denotes contaminated trash
(L) denotes solidified liquid

*Source: AIF Study

TABLE A-III*

OPERATING BWR ANNUAL SOLID WASTE VOLUMES

Plant or Site	Solidified Liquid, ft³/MWe/yr Generated RADW	CHEM	Total	Buried Total	Demineralizer Resin, ft³/MWe/yr Generated RCS	FPCS	CPS	RADW	Total	Buried Total	Filter/Demineralizer Sludge, ft³/MWe/yr Generated RCS	FPCS	CPS	RADW	Total	Buried Total	Cartridge Filters ft³/MWe/yr	Contaminated Trash, ft³/yr
B1	N/D	N/D	N/D	[illegible]	7.6	N/D	N/D	N/D	[illegible]6	6.0	0	0	[illegible]	N/D	N/D	N/D	1.4	1,000
B2	N/D	N/D	1.0	2.3	[illegible]	[illegible]	[illegible]	0	[illegible]8	N/D	0	0	0	[illegible]	0	0	11.5	1,900
B3	0	0	0	0	[illegible]	0	[illegible]	1.6	5.3	5.3	0	0	0	0	0	0	1.7	1,050
B4	0	0.2	0.2	N/D	0	[illegible]	0	0.4	0.4	0.4	0.3	2.3	8.0	0.7	11.3	11.3	[illegible]0	[illegible]1,500
B5	0	0	0	0	[illegible]	0	0	0.6	0.8	1.0	0.2	0.1	3.2	2.9	6.4	8.0	0.0	N/D
B6	0	2.3	2.3	N/D	[illegible]	0	0	0.7	0.7	N/D	0.2	0.6	4.4	1.7	6.9	10.4	N/D	5,7[illegible]
B7	N/D	14.2	14.2	56.1	5	[illegible]	0.2	N/D	0.7	0.7	0.4	0.1	0	3.9	4.4	4.6	0.0	[illegible]
B8	N/D	N/D	N/D	12.5	N/D	N/D	N/D	N/D	N/D	1.0	N/D	N/D	N/D	N/D	N/D	[illegible]	[illegible]	7,900
B9	10.7	12.8	37.5	[illegible]	0.[illegible]	0.3	0.3	0.1	1.4	1.7	N/D	N/D	N/D	N/D	1.9	[illegible]	0.4	[illegible]00
B10	N/D	N/D	N/D	0.5	0	0	1.6	0	1.6	1.6	0.2	0	[illegible]	9.2	9.4	9.1	[illegible]	9,9[illegible]
B11	N/D	N/D	N/D	N/D	0	0	0	2.5	2.5	2.5	13.0	2.5	15.1	0	30.5	30.5	[illegible]1	3,200
B12	0	0	[illegible]	0	[illegible]	[illegible]	0	3.8	3.3	3.3	5.3	2.3	6.[illegible]	3.8	18.1	32.9	[illegible]	5,200
B13	0	6.7	6.7	12.2	0.3	[illegible]	0.3	1.1	2.0	4.4	N/D	N/D	N/D	N/D	20.4	37.5	0.0	22,000
B14	0	0	0	0	0	0	0	0.8	0.8	0.9	0.3	0.9	6.0	5.0	11.2	12.7	0.3	4,[illegible]00
B15	N/D	N/D	0.2	0.3	N/D	N/D	N/D	N/D	0.2	0.4	0.4	0	3.8	0	4.2	[illegible]	[illegible]0	2,800

OPERATING PWR ANNUAL SOLID WASTE VOLUMES

Plant or Site	Solidified Liquid, ft³/MWe/yr Generated RADW	CHEM	Total	Buried Total	Demineralizer Resin, ft³/MWe/yr Generated RCS	SFPCS	RADW	Total	Buried Total	Cartridge Filters ft³/MWe/yr	Contaminated Trash ft³/yr
P1	18.1	0	18.1	39.7	0.4	0	0	0.4	0.4	0.3	250
P2	0	0	0	0	2.9	0	0	2.9	2.9	1.0	6,750
P3	15.8	0	15.8	29.0	0.1	0.1	0	0.2	0.4	0.6	5,150
P4	4.2	0	4.2	7.8	0.1	0.3	0	0.4	0.4	0.6	4,450
P5	2.9	0	2.9	6.4	0.9	0.3	1.0	2.7	2.4	0.2	5,700
P6	1.8	0	1.8	3.3	N/D	N/D	N/D	1.1	1.1	N/D	3,[illegible]00
P7	7.5	[illegible]	[illegible]	[illegible]18	N/D	N/D	N/D	0.2	[illegible]	0.3	12,500
P8	N/D	N/D	N/D	5.8	N/D	N/D	N/D	0.5	0.5	0.2	[illegible]
P9	23.2	[illegible]	23.[illegible]	19.0	0.[illegible]	0.1	0.5	0.7	0.7	N/D	N/D
P10	11.0	0	11.0	27.6	N/D	N/D	N/D	0.5	0.5	[illegible]	6,100
P11	N/D	N/D	11.[illegible]	21.6	0.2	0.2	2.4	2.8	2.8	0.[illegible]	16,000
P12	N/D	N/D	16.6	36.6	N/D	N/D	N/D	N/D	N/D	N/D	N/D
P13	7.7	0	7.7	19.3	0.3	0	0	0.3	0.3	0.1	20,200
P14	1.3	0	1.3	3.3	N/D	N/D	N/D	0.2	0.2	0.[illegible]	2,000

Notes

1. RADW denotes Radwaste System
2. CHEM denotes Chemical
3. RCS denotes Reactor Cleanup System
4. SFPCS denotes Spent Fuel Pool Cleanup System
5. CPS denotes Condensate Polishing System
6. ft³/MWe/yr is the annual volume per net electrical capacity
7. N/D denotes that no data was reported

*Source: AIF Study

TABLE A-IV*

SUMMARY OF ANNUAL LIQUID DISCHARGES FROM SEMI ANNUAL REPORTS OF OPERATING REACTORS

Plant or Site	1969 Volume 10^6 Gal	1969 Ci	1969 Solid[b] Ci	1970 Volume 10^6 Gal	1970 Ci	1970 Solid[b] Ci	1971 Volume 10^6 Gal	1971 Ci	1971 Solid[b] Ci	1972 Volume 10^6 Gal	1972 Volume Ci	1972 Solid[b] Ci
1	0.63	6.4	283		6.7	2.6	0.656	6.2	3.1	2.1	6.7	4.2
2	0.69	~0	163	0.81	~0	6.0	0.59	~0	3.0	2.98	0.02	2.3
3		8.0	8.1		3.6		20.3	30.3	60		16	
4	11.8			5.34	7.8	6.4	13.4	81.1	2.2	14.2	25.4	157
5	0.32	12.6	63	0.28	4.9	14,493	0.12	3.5	2.3	0.094	1.1	21,000
6					2.4	5.3		4.8	3.8	0.34	1.4	5.3
7										0.19	~0	48.1
8	1.13	12.2	53.4	3.13	33.2	316	3.75	5.9	274	9.00	4.8	4,768
9										0.87	48	
10	8.65	0.5		13.8	18.5	3.0	6.35	12.1	5.4	20.7	10	1,324
11				5.78	26	3.7	4.84	32	203	4.15	34.6	265
12					10	4.6		0.9	47.3	0.5	0.3	1,412
13				11.35	12.8	9.5	14.0	23.2	49.2	7.06	22.1	119
14							1.39	0.7	9.6	2.4	0.8	4.9
15				1.55	0.3	0	9.07	19.7	62.6	19.39	51.5	1,640
16							0.37	~0	17.6	.001	~0	88
17				0.3	~0		0.96	0.2	3.5	1.42	1.5	213
18							3.05	~0	~0.1	10.1	2.4	9.2
19										6.51	20.4	110
20							0.29	~0	~0	2.35	6.8	1.8
21										3.96	0.1	~0
22										8.96	~0	~0
23										0	0	17.5
24										1.22	~0	~.08
25										1.53	1.5	19.4
26												
27												
28												
29												
30												
31												
32												
33												
34												
35												
36												

Plant or Site	1973 Volume 10^6 Gal	1973 Ci	1973 Solid[b] Ci	1974 Volume 10^6 Gal	1974 Ci	1974 Solid[b] Ci	1975[a] Volume 10^6 Gal	1975[a] Ci	1975[a] Solid[b] Ci
1	0.73	9.2	3.0	1.8	6.9				
2	4.49	0.02	2.3	7.8	~0	127.6	2.32	~0	
3									
4	4.41	2.8	326	22.77	7.1	62	10.3	4.9	739
5	0.21	2.7	12,000	0.11	1.1	94.5			
6	0.51	2.4	17.6	0.54	4.4	32.8			
7	0.15	0	~0	0.11	~0	20.9			
8	7.13	3.0	570	10.7	7.2	941	53.9	0.6	22.5
9	0.65	36	45	0.46	13	477			
10	3.28	4.2	2,888	1.93	2.6	1,568	2.54	0.4	1,073
11	3.70	40.8	1,005	3.47	25.6	1,933			
12	0.45	0.1	599	0.51	0.1	614			
13	3.52	13.5	15,700	2.25	18.8	2,060			
14	0.9	0.6	97	11.2	0.2	856			
15	2.59	33.4	1,512	281	198	25.7	2.69	125	1,019
16	0	0	393	0	0	2,477	0	~0	2,375
17	1.54	0.8	1,830	1.30	0.4	2,123	0.85	2.2	6,154
18	8.72	21.4	294	4.56	131	736	4.5	12	310
19	3.24	12.4	14,436	1.69	14.2	2,007			
20	5.02	10.0	638	10.05	5.3	4,975	4.54	0.1	127
21	2.2	0.1	4.0	10.6	1.7	44.7	2.96	0.1	50.3
22	25.6	~0	3.2	78.1	1.7	531	15.9	3.1	1,276
23	0.03	~0	23.5	0	0	108			
24	4.23	0.1	16.16	19.9	18.4	50.6	9.75	9.8	573
25	0.21	0.9	566	2.33	4.2	1,465	0.02	0.2	658
26	3.7	2.8	32.7	3.06	3.0	279	1.65	0.8	1,369
27	0	0		0.29	~0	4.6	3.17	~0	6.2
28	0.87	~0.1	~0.1	2.15	0.6	10.1	1.04	<0.1	31.1
29	4.23	~0	0.3	12.5	0.9	63.8	5.2	0.2	117
30				7.98	1.0	80.9			
31				4.80	0.4		0.98	0.3	2.1
32				0.78	~0	8.3			
33				0.21	~0	61.4	~0	~0	49
34				0.78	1.3	6.1	0.47	0.1	75.3
35				3.49	1.4	17.2	0.91	0.1	70.9
36	6.44	~0		7.92	~0	7.6	52.91	~0	1.7

NOTES: a Values for 1975 are for the first six months only.
b For comparison, the total curies shipped off site as solid radwaste are listed.
c Only six months data was reported for the particular item.

*Source: AIF Study

TABLE A-V*

SUMMARY OF DESIGN BASIS SOLID RADWASTE VOLUMES FOR SCHEDULED LWRs

Plant	MWe	Type	Solidified Liquid Generated ft^3	Solidified Liquid Generated ft^3/MWe	Solidified Liquid Buried ft^3/MWe	Demineralizer Resin Generated ft^3	Demineralizer Resin Generated ft^3/MWe	Demineralizer Resin Buried ft^3/MWe	Filter/Demin. Sludge Generated ft^3	Filter/Demin. Sludge Generated ft^3/MWe	Filter/Demin. Sludge Buried ft^3/MWe	Compacted Waste ft^3	Total Solid Waste Generated ft^3	Total Solid Waste Generated ft^3/MWe	Total Solid Waste Buried ft^3/MWe
BWR															
Perry 1,2	2,410	D.B.	5,450	2.3	–	1,900	0.8	–	40,150	16.7	–	1,000	49,000	20.3	–
Zimmer	810	D.B.	2,950	3.7	17.2	550	0.7	1.8	1,700	2.1	5.4	1,500	6,700	8.3	26.3
Shoreham	819	D.B.	4,350	5.3	–	1,900	2.3	–	5,950	7.2	–	2,200	14,400	17.6	–
River Bend 1,2	1,880	D.B.	9,300	4.9	5.9	700	0.4	0.6	5,000	2.7	4.5	3,000	18,000	9.6	12.6
Clinton 1,2	1,910	D.B.	8,700	4.6	9.6	875	0.4	0.9	11,100	5.8	11.0	3,700	24,375	12.8	23.4
Douglas Point 1,2	2,356	D.B.	15,250	6.5	11.0	–	–	–	7,750	3.3	3.6	–	(23,000)	(9.8)	–
Grand Gulf 1,2	2,500	D.B.	14,100	5.6	10.2	650	0.3	–	600	3.2	–	–	(15,350)	(6.1)	–
Brunswick 1	821	F/D	4,300	5.2	7.8	1,200	1.5	1.5	3,350	4.1	–	–	(8,850)	(10.8)	–
Hatch 2	795	F/D	3,000	3.8	–	800	1.0	1.0	16,200	20.4	–	–	(20,000)	(25.2)	–
TOTALS	14,301	–	67,400	–	–	8,575	–	–	91,600	–	–	–	–	–	–

Plant	MWe	Type	Solidified Liquid Generated ft^3	Solidified Liquid Generated ft^3/MWe	Solidified Liquid Buried ft^3/MWe	Demineralizer Resin Generated ft^3	Demineralizer Resin Generated ft^3/MWe	Demineralizer Resin Buried ft^3/MWe	Filter/Demin. Sludge – Cartridge Filter Generated ft^3	Filter/Demin. Sludge – Cartridge Filter Generated ft^3/MWe	Filter/Demin. Sludge – Cartridge Filter Buried ft^3/MWe	Compacted Waste ft^3	Total Solid Waste Generated ft^3	Total Solid Waste Generated ft^3/MWe	Total Solid Waste Buried ft^3/MWe
PWR															
Crystal River	858	D.B.	1,200	1.4	4.9	250	0.3	0.5	300	0.4	0.4	–	(1,750)	(2.1)	(5.8)
South Texas 1,2	2,500	D.B.	1,000	0.4	0.7	2,750	1.1	2.6	300	0.1	0.1	3,000	7,050	2.8	4.6
Byron 1,2	2,240	None	32,700	14.6	21.9	500	0.2	0.6	1,300	0.6	0.6	2,200	36,700	16.4	24.1
Greenwood 1,2	2,416	D.B.	13,000	5.4	–	2,000	0.8	–	1,000	0.4	0.4	6,000	22,000	9.1	–
Farley 1,2	1,720	None	1,000	0.6	1.1	1,600	0.9	–	–	–	–	5,000	(7,600)	(4.4)	–
Pilgrim 2	1,180	None	2,700	2.3	4.1	750	0.6	1.0	500	0.4	0.8	2,400	6,850	5.8	7.9
North Anna	934	F/D	2,100	2.2	3.0	575	0.6	0.6	2,500	2.7	2.7	2,500	7,675	8.2	9.0
Commanche Peak	1,150	F/D	1,250	1.1	2.0	–	–	–	1,200	1.0	1.0	900	(3,350)	(2.9)	–
TOTALS	12,138		14,450			7,625			7,100			19,500	–	–	–

Note: 1) Values in parentheses are based on incomplete data because some information was not included in the PSAR or FSAR.
2) Type of plant refers to method of condensate treatment and is as follows:
D.B. refers to deep bed resin polishing of condensate
F/D refers to filter/demineralizer treatment of condensate
None refers to no treatment of condensate

* Source: AIF Study

TABLE A-VI*

SUMMARY OF ANNUAL BWR RADWASTE VOLUMES BY TYPE

Parameter	BWR Solid Radwaste Type Liquid	Resin	Sludge[a]	Contaminated Trash	Total Waste
Operating Plants					
1. Filter/Demin Plants[b]					
a. Generated Waste, ft^3/MWe/yr	0.6	1.0	12.9	3.6	18.1
b. Buried/Generated[d]	1.8	1.9	1.9	1.0	1.3
c. Solidified Waste, ft^3/MWe/yr[c]	1.1	1.9	25.0	3.6	31.6
d. Percent of total[e]	3%	6%	71%	20%	–
e. Sources of Waste[f]					
Chemical	100%				
RCS			22%		
SFPCS			10%		
CPS			52%		
Radwaste		100%	16%		
2. Deep Bed Resin Plants[g]					
a. Generated Waste, ft^3/MWe/yr	9.1	1.4	6.8	12.4	29.7
b. Buried/Generated[d]	2.5	1.1	1.3	1.0	1.5
c. Solidified Waste, ft^3/MWe/yr	17.3	2.7	13.2	12.9	45.6
d. Percent of total[g]	31%	5%	23%	41%	–
e. Sources of Waste[f]					
Chemical	78%				
RCS		30%	4%		
SFPCS		4%	1%		
CPS		47%	0%		
Radwaste	22%	19%	95%		
Future Plants					
1. Filter/Demin Plants (SARs)[b]					
a. Generated Waste, ft^3/MWe/yr	4.5	1.2	12.2	1.7	19.6
b. Buried/Generated[c]	–	–	–	–	–
c. Solidified Waste, ft^3/MWe/yr[c]	7.7	2.4	23.7	1.7	35.5
d. Percent of Total[c]	23%	6%	62%	9%	–
2. Deep Bed Resin Plants (SARs)[c]					
a. Generated Waste, ft^3/MWe/yr	4.9	0.5	5.3	1.7	12.4
b. Buried/Generated[d]	1.7-4.7	1.6-28	1.1-2.6	1.0	–
c. Solidified Waste, ft^3/MWe/yr[c]	9.4	1.0	10.3	1.7	22.4
d. Percent of Total[e]	39%	4%	43%	14%	–
3. Filter/Demin Plants (ERDA No. 43)[b]					
a. Generated Waste, ft^3/MWe/yr	0.2	0.2	5.6	3.3	9.2
b. Buried/Generated[d]	–	–	–	–	–
c. Solidified Waste, ft^3/MWe/yr[c]	9.2	0.4	10.9	3.3	14.8
d. Percent of Total[e]	1%	2%	61%	36%	–
4. Deep Bed Resin Plants (ERDA 76-43)[g]					
a. Generated Waste, ft^3/MWe/yr	9.9	0.8	3.6	3.3	17.6
b. Buried/Generated[d]	–	–	–	–	–
c. Solidified Waste, ft^3/MWe/yr[c]	18.8	11.6	7.0	3.3	30.7
d. Percent of Total[e]	56%	5%	20%	19%	–

NOTES:
(a) Sludge refers to precoat filter sludge and powdered resin sludge.
(b) Filter/Demin Plants are those that use filter/demineralizers in the Condensate Polishing Systems.
(c) Solidified waste is an estimated value based on average volumes increase reported by operating plants (excluding shielding).
(d) Buried/Generated is the ratio of waste volume actually buried (including shielding) to the waste volumes generated at operating plants.
(e) Percent of Total refers to waste types as generated prior to solidification.
(f) Sources of waste are given for the following systems in addition to the Chemical and Radwaste Systems: Reactor Cleanup System (RCS), Spent Fuel Pool Cleanup System (SFPCS), Condensed Polishing System (CPS).
(g) Deep Bed Resin Plants are those that use deep bed demineralizers in the Condensate Polishing System.

*Source: AIF Study

TABLE A-VII*

SUMMARY OF ANNUAL PWR RADWASTE VOLUMES BY TYPE

Parameters	Liquid	Resin	Filters	Contaminated Trash	Total Waste
	PWR Solid Radwaste Type				
Operating Plants					
1. Plants with CPS[a]					
a. Generated Waste, ft^3/MWe/yr	12.8	0.4	0.2	7.4	20.8
b. Buried/Generated[c]	2.2	1.3	–	–	1.7
c. Solidified Waste, ft^3/MWe/yr[b]	28.4	0.7	0.2	7.4	36.7
d. Percent of Total[d]	62%	2%	1%	36%	–
e. Sources of Waste[e]					
Waste/Boric Acid	50%/50%				
RCS		40%			
SFPCS		10%			
CPS		N/D			
Radwaste		50%			
2. Plants without CPS[f]					
a. Generated Waste, ft^3/MWe/yr	8.3	1.1	0.5	6.0	15.9
b. Buried/Generated[c]	2.1	1.2	–	–	1.6
c. Solidified Waste, ft^3/MWe/yr[b]	18.4	2.0	0.5	6.0	26.9
d. Percent of Total[d]	52%	7%	3%	38%	
e. Sources of Waste[e]					
Waste/Boric Acid	65%/35%				
RCS		52%			
SFPCS		10%			
BRS		N/D			
Radwaste		38%			
Future Plants					
1. Plants with CPS[a] (PSARs)					
a. Generated Wastes, ft^3/MWe/yr	2.5	0.8	0.7	1.8	5.8
b. Buried/Generated[c]	1:8.3.6	1:5.2.7	–	–	–
c. Solidified Waste, ft^3/MWe/yr[b]	5.5	1.6	0.9	1.8	9.8
d. Percent of Total[d]	43%	14%	12%	31%	–
2. Plants without CPS[f] (PSARs)					
a. Generated Waste, ft^3/MWe/yr	8.4	0.4	0.7	1.7	11.2
b. Buried/Generated[c]	N/D	N/D	N/D	N/D	N/D
c. Solidified Waste, ft^3/MWe/yr[b]	18.4	0.8	0.7	1.7	21.0
d. Percent of Total[d]					
3. Plants with Deep Bed CPS[a] (ERDA 76-43)					
a. Generated Waste, ft^3/MWe/yr	11.2	1.2	0.2	2.7	15.3
b. Buried/Generated[c]	N/D	N/D	N/D	N/D	N/D
c. Solidified Waste, ft^3/MWe/yr[b]	24.5	2.4	0.2	2.7	29.8
d. Percent of Total[d]	73%	8%	1%	18%	–
4. Plants with Filter/Demin CPS[a] (ERDA 76-43)					
a. Generated Waste, ft^3/MWe/yr	0.8	0.7	3.5[h]	2.7	7.7
b. Buried/Generated[c]	N/D	N/D	N/D	N/D	N/D
c. Solidified Waste, ft^3/MWe/yr[b]	1.8	1.4	7.0	2.7	12.9
d. Percent of Total[d]	10%	9%	45%	35%	–

NOTES:
(a) Plants with CPS are those having a Condensate Polishing System using either deep bed resin or filter demineralizers.
(b) Solidified Waste is the estimated value based on average volume increase reported by operating plants (excluding shielding).
(c) Buried/Generated is the ratio of waste volume actually buried to that generated based on average volumes reported by operating plants.
(d) Percent of total waste is based on generated waste volumes before solidification.
(e) Sources of waste other than that from waste water or boric acid control are as follows: Reactor Cleanup System (RCS), Spent Fuel Pool Cleanup System (SFPCS), Condensate Polishing System (CPS), Boron Recycle System (BRS), and Radwaste Systems.
(f) Plants without CPS are those that do not have a Condensate Polishing System.
(g) Buried/Generated is waste volume buried divided by volume generated operating plants.
(h) Includes filter/demineralizer sludge.

*Source: AIF Study

technical reports, and reactor plant dockets.

A. Fuel Cycle Wastes

The study concentrated on summarizing the amount of wastes expected to be produced and buried from light water reactor facilities to the year 2000 under varying conditions (e.g. alternative processing methods).

The forecasters expected that during this century no large (1000 MWe or larger) plants would be decommissioned. Some smaller (50-500 MWe) reactors may be decommissioned, but this waste would only slightly affect the waste volume buried for any one particular year of decommissioning. For the study, it was assumed that one plant is decommissioned in each 5-year period from 1985 to 2000, and that 540,000 ft^3 of radioactive waste is generated during each decommissioning.

B. Other Fuel Cycle Wastes

Uranium fuel fabrication wastes were calculated beginning one year before startup of a power reactor and continuing throughout the life of the facility. Wastes were assumed to be accumulated and shipped on an annual basis, starting the year the reactor begins operation. It was further assumed that there was no backlog. The fabrication load was based on the fresh fuel fabrication load projected by the Department of Energy:

a) UO_2 fabrication averages 9.2 ft^3/MTM (equivalent to 275-350 ft^3 per 1000 MWe LWR)

b) MO_x fabrication averages 10.3 ft^3 (equivalent to 300-400 ft^3 per 1000 MWe LWR)

Spent fuel reprocessing wastes were projected on anticipated volumes based on the Department of Energy's "moderate-low" growth case for commercial nuclear power. It was expected that of the total amount of radioactive waste generated, the annual spent fuel from a 1000 MWe LRW is 3100 to 3300 $ft.^3$. Of this total, approximately 2250 $ft.^3$ is assumed to be non-transuranic contaminated waste, which can be delivered to a commercial burial site for disposal.

Wastes from the fuel cycle that were not included in the analysis were:

1) High Temperature Gas Cooled Reactor Wastes (HTGR)
   There was only one HTGR reactor operating and no new HTGR reactors under construction. Waste from the one operatoring reactor was estimated to account for less than 6% of the total installed nuclear capacity and negligible, and therefore not included in the projections.

2) Fast Breeder Reactor Wastes
   Except for demonstration facilities, breeder wastes were considered not to be significant before the end of the century, and would account for less than 3% of the installed capacity, and therefore not included in the projections.

C. Non-Fuel Cycle Waste

Burial site records were used to prepare non-fuel cycle estimates for forecasting. Forecasters compiled the data from 1969 to 1974 inventories, and estimated that approximately 1×10^6 ft^3. was disposed of annually at commercial shallow-land burial sites. It was then postulated that this value would remain relatively constant through the year 2000.

D. Regional Waste

From the available information, AIR determined that approximately 70% of the burial site acreage was located at eastern sites, 30% in the west, and that projected growth rates for nuclear power indicated that 90% of the total would be located in the eastern half of the United States. Therefore, more waste will be generated near eastern burial sites, and those sites will be filled before the western sites. Ninety-three percent of the expansion acreage is in the west, therefore expansion of the total number of possible acreage would not alleviate the problems anticipated in the waste. A likely result is that eastern nuclear power plants will ship their waste to non-eastern sites, and increased transportation costs will be incurred. The ratio of east to west is approximately 90% generation in the east to a 10% generation in the west. Regional boundaries were not delinated in this study.

E. Forecasting Methodology Projection Elements

Table A-VIII provides an analysis of the low-level radioactive waste projection elements found in this study.

F. Forecasting Methodology Assumptions

By nature, employing a combination of statistical, engineering, and design methodologies to formulate shallow-land burial site capacity projections necessitates utilizing a number of assumptions to smooth out irregularties and weaknesses. The following major assumptions were used to arrive at the study's conclusions:

TABLE A-VIII*

LOW-LEVEL RADIOACTIVE WASTE PROJECTION ELEMENTS

1976 AIF Study[a]

Basic Approach:	• National • Regional • Site Capacity/Life

Baseline Data:	• Survey Questionnaires
	  • Nuclear Power Plants
	  • Burial Sites
	  • Fuel Fabrication Facilities
	• Field Visits
	• Architect-Engineering Design Specifications
	• Federal Government Reports
	• Docket Files

Time Horizon:	• 1968-1974 Inventory Totals • January-June 1975 Inventory Totals • Projections to year 2000 by increments of 5 years • Projections of site capacity/life by increments of 5 years

Scenario:	Multiple
	  • High Growth/Low Growth
	  • Steady-State no waste treatment or alternative disposal used
	  • waste treatment or alternative disposal used without backfitting
	  • waste treament or alternative disposal used with backfitting

Waste Characteristics:	• Form of waste (solid, liquid-chemical, resin, sludge, filter, radwaste)
	• Volume (ft^3)
	• Activity (Ci/ft)
	• Source:
	  • Fuel Cycle
	  • Non-Fuel Cycle

National Analysis:	• Projected Cumulative Volumes • Projected Cumulative Acres • Required Commercial Burial Site Acreage • Projected Nuclear Power Plant Growth
Regional Analysis:	• Two geographic regions based on east/west waste generation divison with no specific boundries • Projected percentages
State Analysis:	None

JGB/81

[a]Atomic Industrial Forum. A Survey and Evaluation of Handling and Disposing of Solid Low-Level Nuclear Fuel Cycle Wastes, October 1976.

- All reactors eventually reach a "steady-state" level of waste disposal. This value was obtained by assuming a 10-year leveling-off period and the waste build-up follows an exponential function. The resulting curves gave estimates of 55 ft^3/yr/MW(e) for boiling water reactor's (BWR), and 40 ft^3/yr/MW(e) for pressure water reactors (PWR).

- The 8 reactors on line prior to 1970 do not use the latest processes to treat waste, but were assumed not to have a great impact due to size, etc.

- Major abnormal occurrences experienced by reactors (e.g. condenser leakage, steam generator leakage, fuel leaks, waste system malfunctions) were assumed to be an accepted input to the waste streams and were included in the study.

- Values used were considered to be representative of current technology (demonstrated and used in operating reactors vs design).

- Annual waste value figures reported to the NRC on a semi-annual basis, and data obtained in the AIF survey was correct with little deviation.

- Data on the usable shallow-land burial site acreage and the amount of land that has been filled is valid and correct.

- Sources that were assumed to be negligible and not included were: high-temperature gas cooled reactor wastes and fast breeder reactor waste.

- Government installation and operations waste (e.g. government hospitals, research facilities) was assumed to remain constant.

- One reactor would be decommissioned during each 5-year period from 1985 to 2000 and 540,000 ft^3 of waste will be generated per reactor.

- Non-fuel cycle waste volumes as reflected in disposal site records will remain constant through the year 2000.

- Trench dimensions do not vary significantly from site-to-site.

- Sites are geologically suitable for the purpose of shallow-land burial.
- Sites will remain in full operation until filled to capacity.
- All packaging is uniform, full and to specifications.
- All packages are buried uniformly.
- There will be no changes to waste burial practices.
- Capacity of the site will remain constant with no increase or decrease.
- There will be no changes to the site license requirements.
- There will be no changes to regulations or public laws.

G. Forecasting Methodology Conclusions

The study concludes that existing burial sites (based on a moderate growth rate) will be filled by 1988, 1992 if alternative volume reduction methods are initiated in future reactor plants, and 2000 if alternative methods are initiated and backfitted to existing plants (Table A-IX, Figure A-1 and A-2). Possibly as early as 1980 waste volumes will exceed handling capabilities, and that as eastern sites fill up, radioactive wastes generated in the east will have to be shipped long distances to western sites.

In regard to light water reactors (LWR) specifically, the study concluded that LWR's will generate 89% of the total volume of wastes through 1990, and that 95% of the waste shipped from LWR's is low specific activity waste (1-1/2 - 3 times higher than design values indicated). One per cent of the cumulative waste buried in commercial sites will come from fuel fabrication and reprocessing facilities. Further, that waste volume could

TABLE A-IX

PRESENT COMMERCIAL BURIAL SITE CAPACITY

Site Location	Size[1] (Acres)	Burial Capacity ($\times 10^6$ ft^3)	Estimated Exhaustion Date[2]: Present Waste Generation Rate – Hi Nuc. Growth	Present Waste Generation Rate – Lo Nuc. Growth	Alternative Methods Rate – Hi Nuc. Growth	Alternative Methods Rate – Lo Nuc. Growth	Alternative Methods Backfitted Rate – Hi Nuc. Growth	Alternative Methods Backfitted Rate – Lo Nuc. Growth
Eastern	234	64.4	1986	1987	1988	1989	1994	1997
Western	124	34.1	1998	>2000	>2000	>2000	>2000	>2000
Combined	358	98.5	1988	1990	1992	1994	1999	2000+

(1) Number of acres presently licensed and suitable for shallow land burial of low-level radioactive waste.

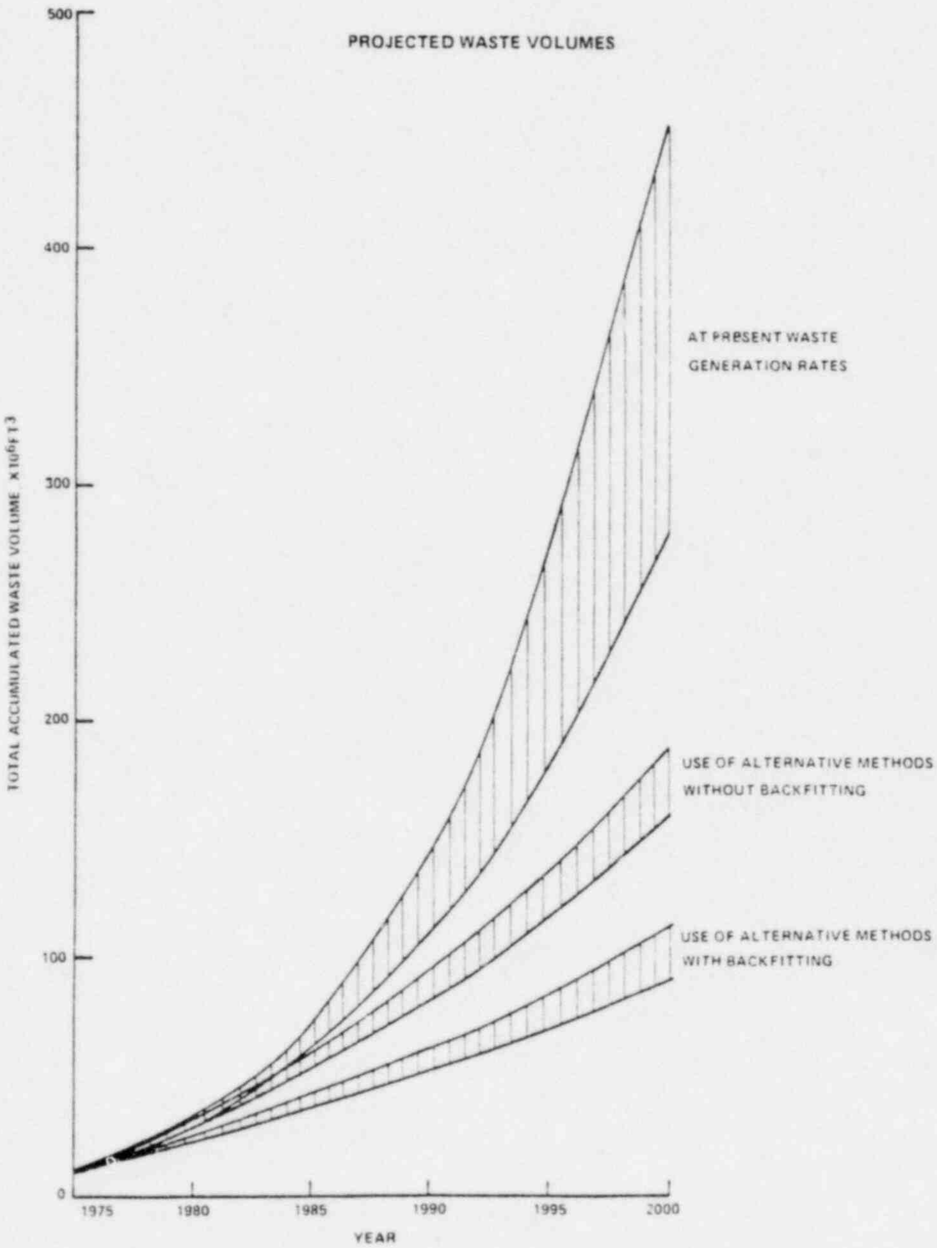
(2) To determine the exhaustion date:
for Eastern Sites: 90% of the waste is generated and buried in the East.
for Western Sites: 10% of the waste is generated and buried in the West.
for the Combined: the assumption is made that waste generated in the East will be shipped to the Western sites to fill all sites at an equal rate.

PROJECTED ACREAGE REQUIRED FOR WASTE DISPOSAL

Year	Cumulative Waste Volume ($\times 10^6$ ft^3)	Cumulative Land Required (Acres): Total	East (90%)	West (10%)
HIGH NUCLEAR GROWTH RATE				
At present waste generation rate:				
1980	21	76	68	8
1985	62	225	202	23
1990	138	502	452	50
1995	265	964	868	96
2000	446	1,622	1,460	162
By use of alternative methods without backfitting:				
1980	21	76	68	8
1985	50	182	164	18
1990	87	316	284	32
1995	131	476	428	48
2000	183	665	598	66
By use of alternative methods of future plants and backfitting existing plants:				
1980	19	69	62	7
1985	37	135	122	13
1990	53	193	174	19
1995	78	284	256	28
2000	110	400	360	40
LOW NUCLEAR GROWTH RATE				
At present waste generation rate:				
1980	20	73	66	7
1985	54	196	177	19
1990	106	385	347	38
1995	177	644	580	64
2000	275	1,000	900	100
By use of alternative methods without backfitting:				
1980	20	73	66	7
1985	46	167	150	17
1990	78	284	256	28
1995	113	411	370	41
2000	152	553	498	55
By use of alternative methods in future plants and backfitting existing plants:				
1980	18	65	59	6
1985	34	124	112	12
1990	48	175	158	17
1995	66	240	216	24
2000	88	320	288	32

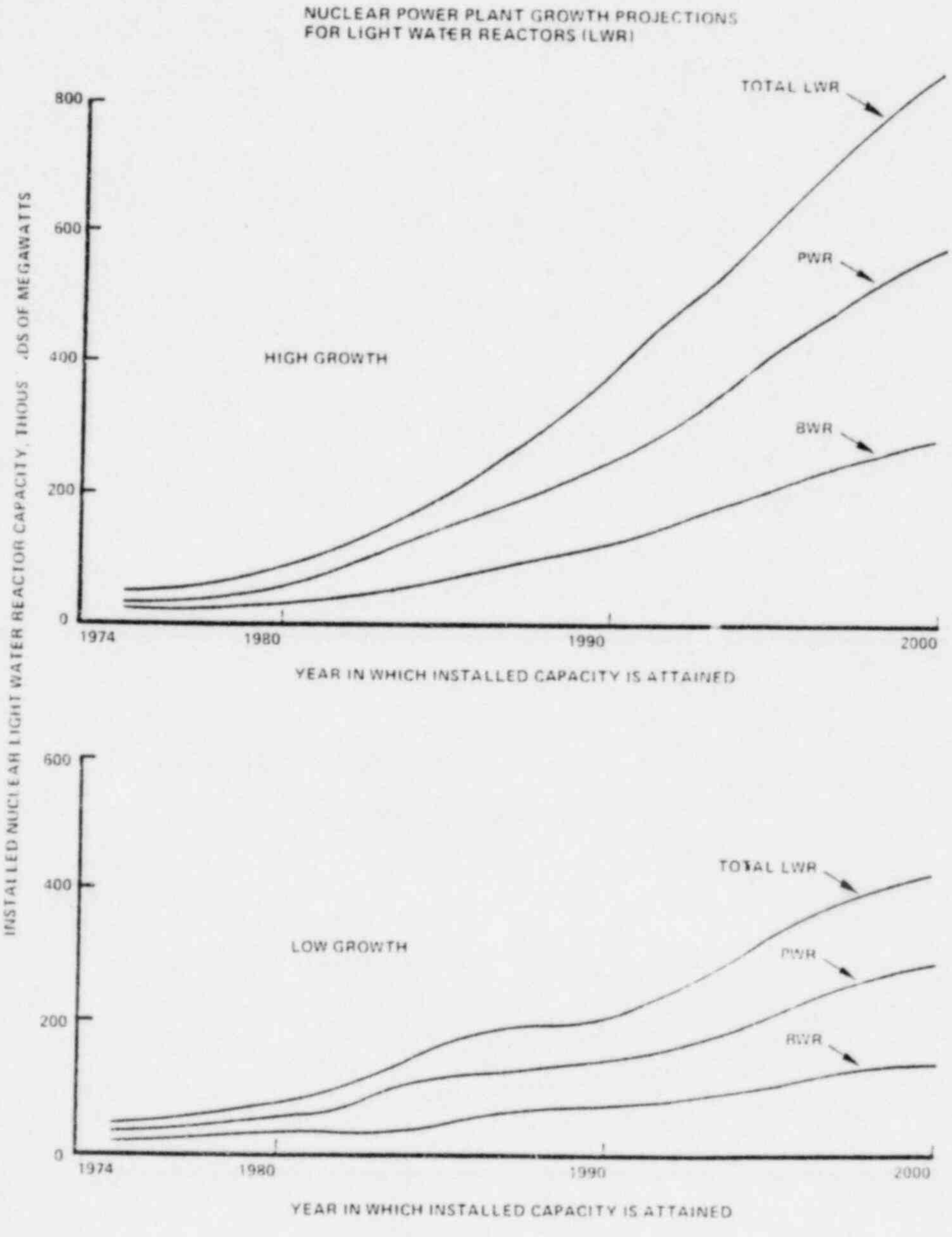
*Source: AIF Study

FIGURE A-1*



*Source: AIF Study

FIGURE A-2*



*Source: AIF Study

be reduced by a factor of 2.5 - 8.0 using currently available, economically feasible reduction processes. The study also recommended that a comprehensive program be undertaken to minimize volumes of waste, that economic alternatives to present radioactive wastes reduction methods be developed, and the onsite storage and disposal of LWR waste be considered.

APPENDIX B

Institutional Radoactive Wastes - 1977

The Nuclear Regulatory commission contracted with the University of Maryland to conduct a selective study of institutional radioactive wastes in 1975, and a follow-up survey in 1977. The primary objective of the study was to characterize, as much as possible, the radioactive wastes shipped for commercial burial, and to obtain some insight into the relationship between use and waste production.

Six hundred and fifty-nine questionnaires were mailed and final analysis was based on 340 coded responses. To obtain response rates for extrapolation, respondents were broken down by entity combination and compared to the same breakdown of total population. Because of the frequent consolidation of responses and the nature of the data, certain simplifying assumptions were used in actual analysis. Data were manipulated by the use of a packaged computer program: Statistical Package for the Social Sciences (SPSS). Limitations in data were supplemented by subjecting the information to general characteristic correlation and behavorial analysis. Suggested aggregate conclusions were calibrated against the estimates found in the EPA study: A Summary of Low-Level Radioactive Waste Buried at Commercial Sites Between 1962-1973, with Projections to the Year 2000.*

*EPA used State Radiological Health Offices non-fuel cycle estimates for calculating the percentages of waste volumes produced for institutional, medical and industrial waste.

Conclusions reached in the survey study indicated that the survey population of large medical and academic licensees shipped an estimated 7,771m^3 of low-level radioactive waste for burial in 1977. Approximately 7% of the waste volume was ascribed to purely medical sources, 79% to sources conducting biological research and 14% to other academic sources. The estimated total activity shipped by the population in 1977 was 1,688 Ci, of which 81% was ^3H. Approximately 540 Ci of ^3H was shipped as depleted tritium targets for neutron generators. Much of the rest was in the form of labeled compounds or labeling reagents used in biological research. It was further found that the fastest growing waste form produced by the population is waste liquid scintillation vials which have undergone a 60% increase in volume since 1975. It was further found that the waste volume produced by the population appears to be increasing linearly, at approximately the same rate as low-level radioactive waste in general.

APPENDIX C

Teknekron Radioactive Waste Management Study

The Nuclear Regulatory Commission contracted with Teknekron, Inc. of Washington, D.C. to provide a modularized, integrated computer model for projecting the quantities, physical characteristics, and associated storage/disposal costs of both fuel cycle and nonfuel cycle commercial radioactive wastes. The projections were to be made on an annual basis with national and regional forecasts to the year 2000.

The preferred approach was not to build a new model, but rather to modify and enhance an existing computer program. The final computer model design was to emphasize flexibility so that new waste treatment and storage technologies could be considered, revised regional definitions could be employed, and other parameters designed so that variations could be exercised without requiring program modifications.

Task 1 of the project consisted of a literature search to identify documentation on existing models (nonproprietary) that have been used for projections of radioactive waste quantities and characteristics, and to become familiar with existing projection methodologies that could be considered as possible starting points.

Six fuel cycle models with characteristics that broadly satisfied NRC's requirements were identified as candidates for examination: NUFUEL, ENFORM, ORSAC, KWIKPLAN, FLYER, and ALPS. Each was reviewed in considerable detail using available documents; the individuals responsible for the most recent versions were also contacted directly. A Reference Table Summary of the information obtained during the documentation review was prepared to identify the capability and limitation parameters of each mode.

Models for non-fuel cycle wastes (medical, academic, research) were found to be virtually nonexistant. Teknekron anticipated that a procedure involving extrapolation of past experience in the generation and storage of radioactive wastes would be adopted to yield a projection.

The Task 1 Final Report, as a result of this survey, recommended that NUFUEL be used as a starting point for the development of the NRC Waste Projection Model. The recommendation was based on the acceptance of NUFUEL as a fuel cycle projection model, its capabilities to analyze fuel cycle flows on a regional basis, its modular design, and other favorable attributes.

Subsequently, contract problems developed and Teknekron, Inc. never completed developing a computer model for NRC.

APPENDIX D

Environmental Protection Agency Studies

In 1971 the Environmental Protection Agency contracted with the state radiological health office, in each of the six states containing low-level radioactive waste disposal sites for commercial waste, to provide them with site inventory data. The inventory data was to include type and quantities of byproduct material, source material, special nuclear material, and liquid waste, buried from the time the site began operation. The data submitted by the states was taken from periodic reports prepared and submitted by the companies operating the burial sites to meet state reporting requirements. The companies tabulated the waste burial data from shipping records prepared by the facilities shipping waste to the burial site. Information supplied enabled EPA to construct a year-by-year annual and cumulative total inventory comparison in addition to a site-by-site comparison (Tables D-I through D-V show EPA's comparison data.

EPA began the initial contractual arrangement as part of its program to formulate federal radiation protection guidance, general environmental standards, and environmental regulations. As part of the technical basis for the supporting documentation, inventory data and projections were needed to indicate the sources and quantities of buried radioactive materials, so the potential impact of shallow land burial disposal could be assessed.

The first forecast was issued in 1974 using inventory data between 1962

TABLE D-I[A]

EPA DEVELOPMENTAL INVENTORY DATA* FOR WASTE VOLUMES (m^3)

Year	Kentucky	Nevada	South Carolina	Illinois	New York	Washington	National annual total	National cumulative total
	Burial Site							
1962		1,861					1,861	1,861
1963	2,206	3,512			522		6,240	8,101
1964	3,872	2,836			6,388		13,096	21,197
1965	5,751	1,988			4,717	668	13,124	34,321
1966	5,556	3,533			4,697	2,402	16,188	50,509
1967	7,820	3,206		2,527	4,946	870	19,369	69,878
1968	8,177	3,576		2,713	4,505	669	19,640	89,518
1969	10,353	4,282		2,012	4,274	438	21,359	110,877
1970	12,520	4,131		2,825	5,096	423	24,995	135,872
1971	13,171	3,584	1,171	4,430	6,362	584	29,302	165,174
1972	15,577	4,301	3,757	5,956	7,054	654	37,299	202,473
1973	10,072	4,076	15,839	8,524	7,497	1,033	47,041	249,514
1974	8,897	4,103	18,244	12,373	8,574	1,411	53,602	303,166
1975	17,109	4,943	18,072	14,116	1,889(c)	1,500	57,629	360,745
1976	13,783	3,864	40,227	13,480	Closed	2,867	74,221	434,966
1977	423(a)	4,742	46,563	17,643	Closed	2,718	72,089	507,055
1978	Closed	8,827	61,566	102(b)	Closed	7,422	77,917	584,972
Total	135,287	67,365	205,439	86,701	66,521	23,659		584,972

*Waste facility operator reports submitted to State Radiation offices based on shipping records of facilities shipping radioactive waste to Commercial low-level waste burial sites.

a. Burial was suspended on Dec. 27, 1977.
b. Burial was suspended on Apr. 8, 1978.
c. Burial was suspended on Mar. 11, 1975.

TABLE D-II[A]

EPA DEVELOPMENTAL INVENTORY DATA** FOR BY-PRODUCT MATERIAL (Ci)

Year	Kentucky	Nevada	South Carolina	Illinois	New York*	Washington	National annual total	National cumulative total
	Burial Site							
1962								
1963	22,556	5,690			1,372		29,618	29,618
1964	147,218	6,477			11,355		165,050	194,668
1965	63,828	6,377			21,515	144	91,864	286,532
1966	52,737	11,974			41,056	1,006	106,773	393,305
1967	23,272	10,894		3,850	51,230	5,378	94,624	487,929
1968	45,578	6,808		2,381	51,675	10,330	116,772	604,701
1969	31,028	9,761		2,192	23,264	55,964	122,209	726,910
1970	56,969	12,304		5,427	36,291	52,620	163,811	890,721
1971	710,147	4,316	4,151	7,895	42,458	23,916	792,883	1,683,604
1972	217,350	5,228	997	4,857	61,208	31,809	321,449	2,005,053
1973	123,779	5,704	42,500	2,834	170,552	57,037	402,406	2,407,459
1974	143,656	23,904	329,043	3,229	55,529	12,773	568,134	2,975,593
1975	289,751	18,388	17,428	6,103	10,273 (c)	113,341	455,284	3,430,877
1976	211,356	4,493	90,204	7,744	Closed	104,306	418,103	3,848,960
1977	267,063 (a)	22,816	390,365	11,147	Closed	7,465	698,856	4,547,863
1978	Closed	5,685	652,061	2,547 (b)	Closed	235,548	895,841	5,443,677
Total	2,406,288	160,819	1,526,749	60,206	577,778	711,837		5,443,677

*Plutonium-238 was subtracted from figures in the column. New York reports Pu-238 as byproduct material instead of special nuclear material, whereas the other states report Pu-238 as special nuclear material.

**Waste facility operator reports submitted to State Radiation offices based on shipping records of facilities shipping radioactive waste to Commercial low-level waste burial sites.

a. Burial was suspended on Dec. 27, 1977.
b. Burial was suspended on Apr. 8, 1978.
c. Burial was suspended on Mar. 11, 1975.

[A] Table compilations from EPA data.

TABLE D-III[A]

EPA DEVELOPMENTAL INVENTORY DATA* FOR SOURCE MATERIAL (kg)

Year	Burial Site: Kentucky	Nevada	South Carolina	Illinois	New York	Washington	National annual total	National cumulative total
1962		296					296	296
1963	5,210	472			7,582		13,264	13,560
1964	5,594	331			10,068		15,993	29,553
1965	568	236			22,220	1	23,025	52,578
1966	690	91			38,325	253	39,359	91,937
1967	5,677	346		3,930	20,275	1	30,229	122,166
1968	6,247	1,043		8,705	6,461	3	22,459	144,625
1969	2,554	290		6,334	80,014	89	89,281	233,906
1970	7,218	323		2,004	31,720	31	41,296	275,202
1971	5,735	428	12,546	212	51,455	607	70,983	346,185
1972	8,258	9,342	1,606	3,596	72,543	3,110	98,455	444,640
1973	9,340	11,460	45,305	2,409	44,107	2,245	114,866	559,506
1974	13,117	9,717	26,961	13,914	61,703	20	125,432	684,938
1975	82,521	1,438	40,375	35,950	16,253 (b)	215	176,752	861,690
1976	75,944	5,000	24,395	3,854	Closed	5,011	114,204	975,894
1977	297 (a)	10,634	166,965	184,814	Closed	2,753	365,463	1,341,357
1978	Closed	77,647	804,670	2,121 (c)	Closed	5,264	889,702	2,231,059
Total	228,970	129,094	1,122,823	267,843	462,726	19,603		2,231,059

*Waste facility operator reports submitted to State Radiation offices based on shipping records of facilities shipping radioactive waste to Commercial low-level waste burial sites.

a. Burial was suspended on Dec. 27, 1977.
b. Burial was suspended on Apr. 8, 1978.
c. Burial was suspended on Mar. 11, 1975.

TABLE D-IV[A]

EPA DEVELOPMENTAL INVENTORY DATA** FOR SPECIAL NUCLEAR MATERIAL (g)

Year	Burial Site: Kentucky	Nevada	South Carolina	Illinois	New York*	Washington	National annual total	National cumulative total
1962		319					319	319
1963	959	41,304			952		43,215	43,534
1964	11,770	172,030			3,273		187,073	230,607
1965	4,261	334,752			2,433	3	341,459	572,066
1966	7,462	5,872			4,999	1,418	19,751	591,817
1967	14,842	22,644		1,238	3,446	<1	42,170	633,987
1968	17,771	8,602		1,754	2,045	<1	30,172	664,159
1969	31,506	5,005		3,843	7,301	32	47,687	711,846
1970	47,562	7,708		5,649	8,273	200	69,392	781,238
1971	72,770	757	13,220	9,934	4,816	15	101,512	882,750
1972	71,443	21,177	46,718	5,898	7,321	832	153,389	1,036,139
1973	46,249	15,164	99,800	6,126	7,710	6,558	181,607	1,217,746
1974	23,850	16,954	110,444	8,144	2,986	5,284	167,662	1,385,408
1975	25,690	29,275	76,983	5,285	1,240 (c)	18,978	157,451	1,542,859
1976	27,474	2,096	122,261	1,736	Closed	24,379	177,947	1,720,806
1977	27,878 (a)	4,597	183,251	5,310	Closed	25,937	246,973	1,967,779
1978	Closed	7,673	220,900	2,134 (b)	Closed	18,312	249,019	2,216,798
Total	431,487	695,939	873,577	57,053	56,795	101,947		2,216,798

*Plutonium-238 was added to the figures supplied by New York State.

**Waste facility operator reports submitted to State Radiation offices based on shipping records of facilities shipping radioactive waste to Commercial low-level waste burial sites.

a. Burial was suspended on Dec. 27, 1977.
b. Burial was suspended on Apr. 8, 1978.
c. Burial was suspended on Mar. 11, 1975.

[A]Table compilations from EPA data.

and 1973. A second forecast was issued in 1978 as an update using inventory data between 1962 and 1976, and a third update was issued in June 1980 using inventory data between 1962 and 1978.

The first two forecasts (1974, 1978) were somewhat similar in outlook although they differed in actual forecast conclusions. The closure of three of the six sites, and changes in site operations and regulations dramatically impacted the 1980 forecast update. Moreover, less optimistic projections for the development of the nuclear power industry led to decreased volume predictions, and necessitated further revisions in the available burial capacity forecasts.

A. Fuel Cycle Waste

The 1974 forecast for fuel cycle waste represented the estimated amount anticipated, based on extrapolated data from the national annual volume buried at commercial sites between 1963 and 1973, rather than on nuclear power growth projections and extrapolated historical data. After this report was issued EPA developed a new basis for projection the expected volume of fuel cycle waste.

For this basis the annual waste volumes from reactor operations were plotted on a linear scale vs the power-generating capacity (in MW(e)) of nuclear power plants for a given span of time. A line was fitted using the least-squares technique. This line then described the relationship between waste volume and power-plant capacity based on historical information. The linear description oversimplified many of the factors influencing waste production (e.g., type of light-water reactor (LWR), load factors, startup difficulties, and backfitting of gaseous and liquid radwaste systems), however EPA felt it provided a valid basis for forecasting. Assuming that a linear fit was adequate for the purpose of prediction, annual volumes of reactor waste were estimated as a function of installed generating capacity:

$$\text{Reactor Wastes} = \frac{0.48\ m^3}{MW(e) \bullet YR} \times \text{cummulative MW (e)}$$

B. Other Fuel Cycle Waste

To determine the contribution from other fuel cycle wastes (uranium conversion and fuel fabrication), EPA took the estimate for all fuel cycle wastes, and subtracted the preliminary reactor operating data for waste shipped to commercial facilities. It was then assumed that the difference between these two figures constituted the other fuel cycle wastes.

The uncertainties surrounding reprocessing prevented developing any basis for waste volume projections. Therefore this aspect was not factored in to the forecast.

C. Non-fuel Cycle Waste

During the time period EPA made their projections, information describing the volume and curi activity from non-fuel sources was not compiled in a single document or reference source. As a result, the agency requested the State Radiological Health Office in each state to determine the percentages of uncompacted waste from non-fuel cycle sources. These figures are as follows:

1979-1980	1981-1990	1991-2000
44%	27%	14%

It was assumed that the waste volume from the non-fuel cycle source represented a constant addition to the waste generated by the fuel cycle source, and a basis for forecasting.

Of the total waste volume, it was further estimated that approximately 30% was produced by sources related to medicine or medical sources, and 10% was generated by universities and industries.

D. Regional Waste

In 1974, the location of the six commercially operated burial sites for low-level waste enabled EPA to develop geographic regions as a projection factor for forecasting. While the original investment decisions on these sites were not based on any formal plan, the resulting distribution of facilities approximated a regional system of low-level waste disposal sites:

West Valley, New York	Northeastern Region
Maxey Flats, Kentucky	Middle Atlantic Region
Barnwell, South Carolina	Southern Region
Sheffield, Illinois	Midwestern Region
Beatty, Nevada	Southwestern Region
Richland, Washington	Northwestern Region

This provided an easy incentive to begin relating data to generation by region, available capacity, and operational life of the site.

The EPA 1974 forecast was the first attempt to relate national projection figures to the regional needs of the continental United States. Forecasts were based on burial record data for both non-fuel cycle and fuel cycle wastes, and on the electric power projections for future fuel cycle wastes.

To arrive at a forecast, EPA made the following assumptions:

a) The continental U.S. was divided into six geographic regions based on the location of the six commercial sites. The boundaries are hypothetical and the calculation and assumptions made did not have any political or regulatory significance.

b) It was assumed that the nuclear facilities within the region would send their radioactive waste to the regional burial grounds.

c) It was also assumed that the nuclear plants planned beyond 1985 Atomic Energy Commission projections would not significantly affect the relative regional power generating capacities.

d) In allocating the national annual volume of waste, the nuclear power electrical capacity within the region was used as the basis for the regional share of fuel cycle wastes.

e) Equal geographical distribution was assumed for non-fuel cycle wastes.

f) Existing sites would not be enlarged.

g) No new sites would be established.

In 1975 the first of three site closings took place.* This action nega-

*Burial was suspended at West Valley, New York on March 11, 1975 due to seeping water containing tritium and SR^{90} from two trench caps. Burial was suspended at Maxey Flats, Kentucky on December 27, 1977 due to leakage in trenches that resulted in onsite migration of burial material. Burial was suspended at Sheffield, Illinois on April 8, 1979 due to filling of available capacity.

tively impacted further regional forecasting by EPA. Figure D-1 illustrates the EPA geographic regional distribution, and Table D-V presents EPA's regional forecast to the year 2000.

E. Forecasting Methodology Projection Elements

Table D-VI provides an analysis of the basic low-level radioactive waste projection elements found in all three EPA studies. The general approach and method were found to be consistent throughout the original study and the two subsequent updates. EPA currently has no plans and has made no budget allocations for a third update.*

F. Forecasting Methodology Assumptions

Although there have been previous speculation on radioactive waste to be generated, with regard to selective aspects of the problem, EPA was the first to correlate fuel cycle and non-fuel cycle radioactive waste information to the available capacity of the commercial waste sites.

Operating data as well as burial volume data had an impact on the basic assumptions used in calculating the forecasts. For example, the assumption used for a standard burial trench capacity in the 1974 and 1978 studies, and the 1980 study remained the same for trench size, but differed in total burial volume projections. A standard trench was assumed to be 300 feet

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*W.H. Holcomb, U.S. Environmental Protection Agency, personal telecommunication with J.G. Braun, U.S. Nuclear Regulatory Commission, Division of Waste Management, March 10, 1991.

FIGURE D-1

EPA GEOGRAPHIC REGIONS FOR LOW-LEVEL RADIOACTIVE WASTE DISPOSAL*

TABLE D-V*

EPA 1974 ESTIMATED CUMULATIVE VOLUME OF WASTE GENERATED IN EACH REGION THROUGH THE YEAR INDICATED

Region	Volume[a]				
	1973[b]	1975[c]	1980[b]	1990[b]	2000[b]
Northeastern (West Valley, N.Y.)	2.0	2.9	6.4	37.4	211.4
Middle Atlantic (Maxey Flats, Ky)	3.4	4.9	7.9	27.9	134.9
Southern (Barnwell, S.C.)	.8	1.1	5.1	41.1	249.1
Midwestern (Sheffield, Ill.)	1.0	1.4	4.9	39.5	238.5
Southwestern (Beatty, Nev.)	1.5	2.1	4.1	16.1	72.1
Northwestern (Richland, Wa)	.5	.7	2.7	13.7	59.7
National Cumulative Total	9.2	13.1	31.1	175.7	965.7

[a] Volume is measured in 10^6 cubic feet

[b] Obtained from burial site shipping data

[c] Calculated using the partitioning of waste based upon cumulative volume up to 1973

* Source: EPA Studies

TABLE D-VI

LOW-LEVEL RADIOACTIVE WASTE PROJECTION ELEMENTS

	1974 Study[a]	1977 Study[b]	1979 Study[c]
Basic Approach:	• National • Regional • Site Capacity/Life	• National • Site Capacity/Life	• National • Site Capacity/Life
Baseline Data:	Waste facility reports submitted to State Radiation Offices based on shipping records prepared by facilities shipping waste to the six commercial burial sites (Sheffield, Maxey Flats, West Valley, Beaty, Barnwell, Richland)	Waste facility reports submitted to State Radiation Offices based on shipping records prepared by facilities shipping waste to the three operating commercial sites (Beaty, Richland, Barnwell) and the three closed commercial sites (Sheffield, Maxey Flats, West Valley)[d]	Waste facility reports submitted to State Radiation Offices based on shipping records prepared by facilities shipping waste to the three operating commercial sites (Beaty, Richland, Barnwell) and the three closed commercial sites (Sheffield, Maxey Flats, West Valley)[d]
Time Horizon:	• 1962-1973 Inventory Totals • Projection to year 2000 by increments of 10 years • Projection of site capacity/life	• 1962-1976 Inventory Totals • Projection to year 2000 by increments of 10 years • Projection of site capacity/life	• 1962-1978 Inventory Totals • Projection to year 2000 by • increments of 10 years • Projection of site capacity/life
Scenario:	Single	Single (with qualifications)	Single (with qualifications)

Waste Characteristics:	• Type of Waste (byproduct, source, special nuclear)
	• Form of Waste (solid, liquid)
	• Volume (m^3)
	• Appropriate Measurements/Radioactivity (Curies, grams, lbs, gals)
	• Source
	  • Fuel Cycle[e]
	  • Non-Fuel Cycle[f]
		• Type of Waste (byproduct, source, special nuclear)
		• Form of Waste (solid)
		• Volume (m^3)
		• Appropriate Measurements/Radioactivity (Curies, grams, lbs, gals
		• Source
		  • Fuel Cycle[e]
		  • Non-Fuel Cycle[f]
			• Type of Waste (byproduct, source, special nuclear)
			• Form of Waste (solid)
			• Volume (m^3)
			• Appropriate Measurements/Radio-
			• activity (curies, grams, lbs, gals)
			• Source
			  • Fuel Cycle[e]
			  • Non-Fuel Cycle[f]

National Analysis:	• Annual volume and totals • Cumulative volume and totals • Projected annual volume • Projected cumulative volume	• Annual volume and totals • Cumulative volume and totals • Projected annual volume • Projected cumulative volume	• Annual volume and totals • Cumulative volume and totals • Projected annual volume • Projected cumulative volume
Regional Analysis:	• Six geographic regions based on location of six commercial burial sites, with hypothetical boundries bearing no political, social and regulatory significance • Projected volume • Projected percentage of nuclear electric power capacity assumed for fuel cycle wastes • Equal geographical distribution assumed for non-fuel cycle wastes	Reiteration of 1974 Study data	None
State Analysis:	None	None	None

JGB/81

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[a] J.F. O'Connell and W.F. Holcomb, "Low-Level Radioactive Wastes Buried at Commercial Sites Between 1962-1973, with Projections to the Year 2000", Radiation Data and Reports, 15(12), pp. 759-767, December 1974.

[b] W.F. Holcomb, "A Summary of Shallow Land Burial of Radioactive Wastes at Commercial Sites Between 1962 and 1976 with Projections", Nuclear Safety, 19(1), pp. 50-59, January-Februrary 1978.

[c] W.F. Holcomb, "Inventory (1962-1978) and Projections (to 2000) of Shallow Land Burial of Radioactive Wastes at Commercial Sites: An Update", Nuclear Safety, 21(3), pp. 380-388, May-June 1980.

[d] Burial was suspended at Sheffield on April 8, 1979 due to filling of available capacity. Burial was suspended at Maxey Flats on December 27, 1977 due to leakage in trenches that resulted in on-site migration of burial material. Burial was suspended at West Valley on March 11, 1975 due to seeping water containing tritium and SR^{90} from two trench caps.

[e] Annual total volumes of fuel cycle wastes are calculated by using a list of nuclear electric power plants in operation, under construction and projected (on order) for any given year.

[f] Detailed information concerning non-fuel cycle low-level radioactive waste is unavailable at this time due to reporting methods used for shipping manifests and subsequently for site inventory.

long (91m) x 40 f?et wide (12.2m) x 20 feet deep (6.2m), 240,000 feet^3 (6800m^3) with 20 feet (6.1m) of spacing between trenches. The burial volume projections were:

a) 1974 and 1973 Volume Projection: 143,000 ft^3 per trench assuming that the top meter of the trench depth will not be used and that a 30% void space will exist for each trench.

b) 1980 Volume Projection: 3460m^3 per trench assuming that the top meter of the trench will not be used and a 40% void space will exist fore each trench.

The adjusted data projections in the 1980 report were based on the State of Nevada's Division of Health technical recommendation that trench void space be increased by 10% with a 60% utilization factor rather than a 70% utilization factor.

Because information was basically empirical in nature, a number of general suppositions were necessary to speculate on expected impacts. Those assumptions were as follows:

- A "steady-state environment" will continue to prevail.
- Sites are geologically suitable for the purpose of shallow-land burial.
- Sites will remain in full operation until filled to capacity.
- All packaging is uniform, full and to specification.
- All packages are buried uniformly.
- There will be no changes to waste burial practices.
- Capacity of the site will remain constant with no increase or decrease.

- Operational life of the site will not increase or decrease for any reason.
- Size of the site will not increase or decrease.
- No additional sites will be created.*
- Waste receipt is recorded as originating from the state in which it was generated.
- There will be no changes in waste generation characteristics.
- Uniform record keeping is practiced at all sites.
- Inventory records are valid and accurate.
- Planned nuclear electric power plant projections will not significantly affect the relative regional power capacity.
- Fuel cycle wastes are from once-through cycle with the annual waste volumes from reactor operation plotted on a linear scale vs the power-generating capacity.
- Waste has not undergone volume reduction (compaction/incineration).
- There will be no changes to the site license requirements.
- There will be no changes to regulations or public laws.

G. EPA Forecasting Methodology Conclusions

The 1974 report served as a vehicle to:

a) present accumulated inventory data for radioactive

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*Until mid-1979 the NRC viewpoint on licensing new sites was that it would be unadvisable for any new shallow-land burial facilities to be licensed unless an "urgent need" was identified - NRC Task Force Report on Review of the Federal/State Program for Regulation of Commercial Low-Level Radioactive Waste Burial Grounds, Report NUREG-0217, March 1977. The temporary closure of burial sites by the Governor of Washington and Nevada, and the limiting of waste volume accepted by the Governor of South Carolina and the Governor of Washington (South Carolina's limit on waste receipts will be reduced to 100,000^3 a month by October 1981) necessitated a change in the NRC viewpoint.

waste buried at commercial facilities;

b) point out some of the more obvious trends; and

c) focus attention on the possible magnitude of future low-level radioactive waste disposal problems associated with commercial shallow-burial sites.

The 1978 and 1980 reports updated the inventory data for radioactive waste buried at commercial facilities, and adjusted future site capacity impact estimates. Table D-VII presents a site capacity comparison of prediction data, and Table D-VIII presents a comparison breakdown of fuel cycle and non-fuel cycle wastes for annual volumes.

Originally it was believed that the total annual volume of radioactive waste received at commercial burial sites was growing at an exponential rate. EPA devised an exponential projection to the year 2000 by drawing a straight line through the data points representing the early years of commercial waste burial. Figure D-2 is a graphic comparison of the 1974, 1977, and 1979 exponential data forecasts. This comparison pointedly illustrates the considerable decline in radioactive waste predicted.

Interpretation of inventory data, and the assumptions, estimates, and projections, made about existing burial facilities by EPA indicated that for:

a) 1974

1) The volume and quantity of low-level waste was growing rapidly.

TABLE D-VII

EPA PROJECTED CAPACITIES OF EXISTING LOW-LEVEL WASTE COMMERCIAL BURIAL SITES *

Burial Site	Size (ha)			Possible Numer of[b] Standard Trenches			Total Burial Capacity (10^6 m^3)			Date Current Capacity Exhausted		
Year of Forecast:	1974[a]	1977	1979	1974	1977	1979	1974[c]	1977	1979	1974	1977[d]	1977[d]
West Valley, N.Y.	22	8.9	8.9	50	50	0	7.2×10^6	0.20	Closed[h]	1981	N/P	N/P
Maxey Flats, Ky.	330	102.0	102.0	750	580	0	1.1×10^8	2.20[e]	Closed[i]	1998	N/P	N/P
Barnwell, S.C.	270	110.0	110.0	614	604	604	8.8×10^7	2.40	2.40	1993	N/P	N/P
Sheffield, Ill.	22	8.9	8.9	50	50	0	7.2×10^6	0.20	Closed[j]	1981	N/P	N/P
Beatty, Nev.	80	32.0	32.0	182	179	179	2.6×10^7	0.74[f]	0.60	1992	N/P	N/P
Richland, Wa.	100	40.0	40.0	227	223	223	3.2×10^7	0.91	0.91	1994	N/P	N/P
								6.70 (4.60)[g]	3.93			

[a] Size is by Acre

[b] These numbers may differ from site plot plans in which trenches may not be of the standard type

[c] Current burial capacity as of 1974

[d] Adjusted year projections were not provided

[e] Reflects the possibility that the site may have a 50% lower capacity than first projected

[f] The Nevada Division of Health recommends a utilization factor of 0.6, which reduces the 0.74 to 0.47

[g] The figure is a revised total reflecting the reduced capacity estimates for Maxey Flats and Beatty

[h] Burial was suspended on March 11, 1975 due to seeping water containing tritium and ^{90}SR from two trench caps

[i] Burial was suspended on December 27, 1977 due to leakage in trenches that resulted in on-site migration of burial material

[j] Burial was suspended on April 8, 1979 due to filling of available capacity

*Table compilations from EPA data.

TABLE D-VIII

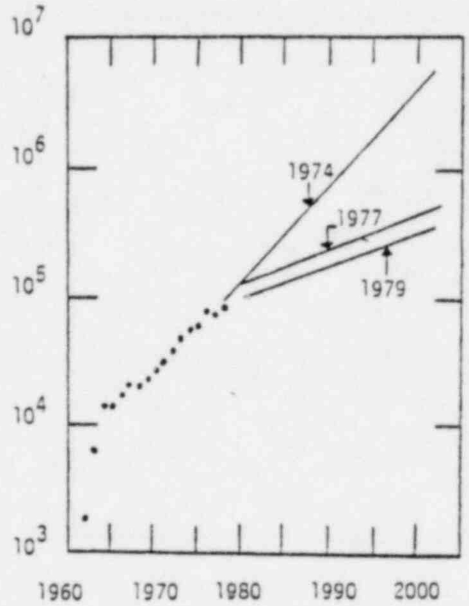
EPA FORECASTED AVERAGE ANNUAL VOLUME OF LOW-LEVEL WASTE (10^6 m^3/Yr)*

Year of Forcast	FUEL CYCLE WASTES			NON-FUEL CYCLE WASTES			TOTAL WASTE		
	1976 - 1980	1981 - 1990	1991 - 2000	1976 - 1980	1981 - 1990	1991 - 2000	1976 - 1980	1981 - 1990	1991 - 2000
1974[a]	2.000	10.600	68.000	1.600	3.900	11.000	3.600	14.500	79.000
1977	0.057	0.300	1.930	0.045 44% (estimated %)	0.110 27% (estimated %)	0.310 14% (estimated %	0.102	0.410	2.240
1979	0.050	0.107	0.198	0.039 44% (estimated %)	0.040 27% (estimated %)	0.033 14% (estimated %	0.089	0.147	0.231

[a]Figures are 10^6 ft^3/Yr

*Table compilations from EPA data.

FIGURE D-2



EPA FORECASTED TOTAL AVERAGE ANNUAL VOLUME OF LOW-LEVEL WASTE (10^6 m^3/Yr)*

Year of Forecast	1976 - 1980	1981 - 1990	1991 - 2000
1974[a]	3.600	14.500	79.000
1977	0.102	0.410	2.240
1979	0.089	0.147	0.231

[a] figures are $10^6 ft^3$/Yr

*Table compilations from EPA data.

2) If no changes to present practices or trends occur, two sites will be closed by 1985 (West Valley, Sheffield) and all six sites by 1998. If the sites were filled on the basis of load shifting to the other burial sites as each site reached its capacity, then the last closure would be 1992.

b) 1978

1) The volume and quantity of low-level waste was growing rapidly.

2) If no changes to present practices or trends occur, the last site will be filled by 1992.

c) 1980

1) The volume and quantity of low-level waste is continuing to increase each year.

2) The rate of waste generation appears to be slowing down.

3) If no changes to present practices or trends occur, the last site will be filled by mid-1990's - uncertainties surrounding the burial sites limit this projection and all commercial sites could be filled by mid-1980's.

Other trends and observations made by EPA were:

a) Relating radioactivity buried is difficult since the activity concentrations in the waste depends upon the originating source and use of radioactive material at the source.

b) Sites were initially established to receive non-fuel cycle wastes (medical, research, industrial) and have been increasingly used for a growing nuclear electric power industry.

c) Growth of the nuclear electric power industry will continue to dramatically increase fuel cycle wastes until they surpass non-fuel cycle wastes by large percentages (1980 - 56%, 2000 - 86%).

d) Nuclear electric power growth can be correlated and reflected in the rate of fuel cycle low-level waste growth increases at the burial sites.

e) As a consequence of recalculated nuclear electric power generating projections, waste volume projections through the year 2000 have been slowing down.

f) Changes in licensing requirements and regulations significantly impact inventories (1972 requirement for solidification of liquid waste prior to shipment and 1974 exclusion of TRU wastes if it exceeds 10 nCi/g).

g) A redistribution of wastes has resulted from the closing of three commercial burial sites.

h) If operational problems occur at a burial site, little flexibility exists for managing low-level waste for the next 10-20 years, therefore new burial sites must be established soon to insure health, safety, and environmental protection.

i) The life of the burial sites can be extended by reducing the volume of estimated wastes through volume reduction (compaction, incineration) - if compaction is practiced (possible reduction of 3 to 5) the last site will be filled by the year 2000.

j) A more detailed analysis of low-level waste is needed to:

- identify suitable new sites;
- improve low-level radioactive waste volume projections;
- determine accurate capacity of burial sites; and
- characterize wastes generated by decommissioning of nuclear facilities.

k) Projections need to be revised in the near future because of:

- uncertainties in uranium conversion, fuel cycle fabrication and fuel reprocessing; and
- continued decrease and rescheduling in the rate of the nuclear electric power industry.

APPENDIX E

NUS State-by-State Assessment of Low-Level Radioactive Waste Shipped to Commercial Burial Grounds

In 1978 and 1979 the trend toward declining burial space with increasing waste volume; combined with the problems of establishing new burial grounds; and the temporary closing of two of the three open sites and reduced volume at the third; demonstrated a need to better characterize commercial low-level radioactive waste. The Department of Energy recognizing the need for better characterization, contracted with the NUS Corporation, to provide a state-by-state assessment of radioactive waste shipped to commercial burial grounds report.

NUS first obtained site inventory data directly from the commercial burial site operators. The commercial burial site companies in turn had tabulated the waste burial data from shipping records by the facilities shipping waste to the burial sites.

NUS, in addition, also obtained existing published data (e.g. NRC & DOE records and reports), and reports that could be interpolated from a national to a state basis (i.e. Institutional Radioactive Wastes, NRC Report NUREG/CR-0028, University of Maryland, Radiation Safety Office; October 1979). They were used as part of the basis for the assessment.

Because the aforementioned data sources did not fully characterize the waste volumes, waste volumes classified as industrial source needed to be apportioned for each state. To calculate this, the remaining volume was spread over the United States, in proportion to the population for the Agreement States, and by ratio of the number of state licensees to the total NRC industrial licensees for the non-Agreement States.

A preliminary report was issued in 1979 and a full update assessment report in November 1980. The final report provided a national profile, a site profile, and profiles by category: government, fuel cycle, non-fuel cycle with an institutional and industrial breakdown for all 50 states.

A. Fuel Cycle Waste

To assess the amount of fuel cycle waste, NUS obtained summary information on commercial nuclear powerplant wastes from semiannual reports submitted to NRC. 1979 calendar year data was used where available. When reported data was not available, NUS communicated directly with the utility. Where the data reported by utilities provided only the overall quantity and radioactivity, tables were devised to provide the breakdown. These tables were based on the average waste generation rates established in the report: Waste Inventory Report for Reactor and Fuel-Fabrication Facility Waste.

B. Non-Fuel Cycle Waste

When this report was compiled, there were no quantitative reports in the public domain on the specific volumes and activities from the industrial and institutional sectors. The public record data for commercial nuclear power plants and for a major portion of the government waste allowed NUS to compile by differences the institutional and industrial volume and radioactivity. Factored into the final estimates were data extrapolation from secondary sources.

C. Government Waste

The DOE SWIMS Report (Solid Waste Information Management System - Actual Solid Wastes Generated for Fiscal Year 1979) summarizes the quantities of reported solid radioactive wastes generated by government installations. NUS extracted data on low-level radioactive waste sent to commercial burial grounds and excluded all other information. Data included records from the U.S. Navy nuclear-powered ships and their support facilities, but excluded data from other military departments (e.g. Army and Air Force). Waste from these other military commands does not constitute a significant volume of waste and therefore NUS included the information in the industrial and institutional sector of the report.

D. State-by-State Waste

NUS obtained the volume and curie values given for each state directly from the commercial burial site operators. The total for each state was the sum of the volume and radioactivity by burial site. The report noted that for some states, the amount of waste which is in the institutional/industrial category may not represent the actual volume generated by firms in that state. Burial ground records list volumes from broker companies by the state of the home office (broker companies collect material from several states and repackage or consolidate shipments under one radioactive shipping record).

E. Assessment Methodology Elements

Table E-I provides an analysis of the low-level radioactive waste assessment elements found in the 1980 report. NUS currently is prer ring a 1981 report to be released later this year.*

F. Assessment Methodology Conclusions

Table E-II presents the NUS assessment conclusions. The report presents as a hypothetical scenario of possible low-level commercial radioactive waste distribution disposed of by shallow land burial. It is valid only to the extent the reader supports the author's methodology, and to the extent the reader understands the limitations built into the data. It in no way projects a forecast for future waste or impact to site capacity.

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*Edward Jennrich, EG&G, Idahl, personal telecommunication with J.G. Braun, Division of Waste Management, U.S. Nuclear Regulatory Commission, April 17, 1981.

TABLE E-I

LOW-LEVEL RADIOACTIVE WASTE ASSESSMENT ELEMENTS

1980 NUS Study[a]

Basic Approach:	• National • State-by-State • Site Distribution
Baseline Data:	• Waste Facility Records (Barnwell, Beatty, Richland) • NRC Licensing Statistics o Nuclear Power Reactors o Radioactive Materials • U.S. Population Records • Military Sector Waste Reports (Navy only)
Time Horizon:	• 1979 Inventory Totals • 1979 Estimated Distributions • 1978 & 1979 Total Waste Volume Comparison by State
Scenario:	Single
Waste Characteristics:	• Form of Waste (solid) • Volume (m^3) • Source • Non-Fuel Cycle • Fuel Cycle • Radioactivity (ci)
National Analysis:	• 1979 Total Volume • 1979 Total Percentages by Source • 1979 Source Totals • Non-Fuel Cycle[b] • Fuel Cycle[c] • 1979 On-Line Nuclear Power Reactors
Regional Analysis:	None
State Analysis:	• Individual State Analysis • Total State Volume (m^3) at Commercial Facilities • Total State Percentages • Total Number of On-Line Commercial Power Reactors • Total Fuel Cycle Wastes • Volume (m^3) • Radioactivity (ci) • Total Non-Fuel Cycle Wastes • Total Number of Industrial Licenses • Total number of institutional licensees • Estimated Total State Volume (m^3) • Estimated Total State Radioactivity (ci) • Total Number of Government/Military • (Navy) Wastes from the State • Total Volume (m^3) of State Wastes Disposed of at a Commercial Site • Total Radioactivity (ci) of State Wastes Disposed of at a Commercial Site • 1979 Waste Distribution Comparison for all 50 States • 1979 Waste Volume (m^3) Comparison for all 50 States

JGB/81

[a]Guilbeault, B.D. The 1979 State-by-State Assessment of Low-Level Radioactive Waste Shipped to Commercial Burial Grounds, Report NUS-3440, November 1980, Prepared by NUS Corporation for EG & G Idaho, Inc., U.S.DOE Subcontract: K-5108, Task 23.

[b]Detailed information concerning non-fuel cycle low-level radioactive waste is unavailable at this time due to reporting methods used for shipping manifests and subsequently for site inventory.

[c]Annual total volumes of fuel cycle wastes are calculated by using a list of nuclear electric power plants in operation, under construction, and projected (on order)

TABLE E-II *

State-By-State Assessment of 1979 Low-Level Radioactive Waste Disposal at Commercial Facilities[a]

State	Disposal of at[b] Commercial Facilities: Total Volume [m³]	Disposal of at[b] Commercial Facilities: Total Radioactivity [Ci]	Percentage[b] By Source: Institutional and Industrial %	Percentage[b] By Source: Commercial Power Reactors %	Percentage[b] By Source: Government and Military (Navy) %	Percentage[b] By Facility: Barnwell, S.C.	Percentage[b] By Facility: Beatty, Nev.	Percentage[b] By Facility: Richland, Wash.	Institutional[e] and Industrial: Institutional[c] Licensees	Institutional[e] and Industrial: Industrial[c] Licensees	Institutional[e] and Industrial: Estimated[d] Volume [m³]	Institutional[e] and Industrial: Estimated[d] Radioactivity [Ci]	Government and[f,g] Military (Navy): Number of Installations	Government and[f,g] Military (Navy): Volume [m³]	Government and[f,g] Military (Navy): Radioactivity [Ci]	Commercial Power[h] Reactors: Number of Installations	Commercial Power[h] Reactors: Total Volume [m³]	Commercial Power[h] Reactors: Total Radioactivity [Ci]
Alabama [AL][A,B]	3,672	9,543	< 1%	> 99%	0%	100%	0%	0%	115	233	< 1	3,975	0	0	0	4	3,688	5,568
Alaska [AK]	< 1	< 1	100%	0%	0%	12%	0%	88%	7	20	< 1	< 1	0	0	0	0	0	0
Arizona [AZ]	54	61	100%	0%	0%	2%	64%	33%	98	173	54	61	0	0	0	0	0	0
Arkansas [AR][A,B]	265	180	< 1%	> 99%	0%	97%	2%	1%	162	138	< 1	163	0	0	0	2	279	17
California [CA][C]	4,342	83,281	30%	6%	64%	< 1%	68%	31%	687	1,324	1,315	31,385	5	2,751	48,000	3	276	3,446
Colorado [CO]	225	25	100%	0%	0%	2%	88%	10%	70	364	225	25	0	0	0	1	0	0
Connecticut [CT][A]	3,970	2,764	5%	92%	3%	98%	0%	2%	53	151	203	< 1	3	135	7	3	3,632	3,241
Delaware [DE]	120	< 1	100%	0%	0%	100%	0%	0%	11	27	120	< 1	0	0	0	0	0	0
Florida [FL]	2,592	88,345	14%	86%	0%	> 99%	0%	< 1%	281	411	352	86,605	0	0	0	4	2,240	1,740
Georgia [GA]	1,261	820	22%	78%	0%	100%	0%	0%	241	248	283	480	0	0	0	2	978	340
Hawaii [HI]	83	10	31%	0%	69%	0%	0%	100%	12	50	26	8	1	57	2	0	0	0
Idaho [ID]	7	8	100%	0%	0%	1%	0%	99%	22	90	7	8	0	0	0	0	0	0
Illinois [IL][D]	6,758	9,044	47%	36%	17%	72%	9%	19%	250	436	3,173	1,131	2	1,154	120	7	2,431	7,793
Indiana [ID}	27	1	100%	0%	0%	0%	40%	60%	113	168	27	1	0	0	0	0	0	0
Iowa [IO]	961	1,216	4%	83%	13%	96%	0%	4%	51	88	38	69	1	125	400	1	798	802
Kansas [KS]	10	3	100%	0%	0%	9%	91%	0%	125	187	10	3	0	0	0	0	0	0
Kentucky [KY]	194	37	100%	0%	0%	49%	1%	50%	93	152	194	37	0	0	0	0	0	0
Louisiana [LA]	19	1	100%	0%	0%	97%	0%	3%	280	290	19	1	0	0	0	0	0	0
Maine [ME]	416	555	12%	88%	0%	100%	0%	0%	34	47	52	< 1	0	0	0	1	364	2,771
Maryland [MD][D]	978	2,271	56%	44%	0%	90%	< 1%	9%	96	215	546	1,091	0	0	0	2	432	1,174
Massachusetts [MA][D]	4,860	138,146	33%	67%	0%	83%	< 1%	16%	143	263	1,597	115,829	0	0	0	2	3,263	22,317
Michigan [MI][A]	2,150	875	25%	75%	0%	75%	13%	7%	175	326	537	< 1	0	0	0	4	1,613	1,006
Minnesota [MN]	1,461	13,315	84%	16%	0%	43%	3%	54%	74	130	1,232	97	0	0	0	3	229	13,218
Mississippi-[MS]	68	54	59%	0%	41%	100%	0%	0%	101	117	40	53	1	28	1	0	0	0
Missouri [MO]	329	304	100%	0%	0%	42%	17%	41%	122	160	329	304	0	0	0	0	0	0
Montana [MT]	3	32	100%	0%	0%	67%	0%	33%	25	49	3	32	0	0	0	0	0	0
Nebraska [NB][A,B]	801	140	< 1%	> 99%	0%	32%	66%	2%	36	69	< 1	12	0	0	0	2	809	128
Nevada [NV]	4	62	100%	0%	0%	3%	97%	0%	28	60	4	62	0	0	0	0	0	0
New Hampshire [NH]	77	3	100%	0%	0%	100%	0%	0%	31	42	0	0	1	85	3	0	0	0
New Jersey[D]	3,008	7,450	40%	60%	0%	84%	0%	16%	134	394	1,191	6,000	0	0	0	2	1,817	1,470
New Mexico [NM][A]	80	1	26%	0%	74%	< 1%	38%	62%	42	123	21	< 1	1	59	4	0	0	0
New York [NY][D]	9,572	78,961	61%	32%	7%	75%	13%	12%	584	584	5,869	72,104	2	674	1,630	6	3,029	5,227
North Carolina [NC][A,D]	5,304	4,504	42%	58%	0%	97%	0%	3%	179	245	2,211	< 1	0	0	0	2	3,093	5,372
North Dakota [ND]	2	< 1	100%	0%	0%	94%	0%	6%	30	61	2	< 1	0	0	0	0	0	0
Ohio [OH]	1,905	5,632	43%	14%	43%	98%	1%	1%	208	422	825	5,607	1	820	22	1	260	3
Oklahoma [OK]	21	266	100%	0%	0%	5%	95%	< 1%	68	157	21	266	0	0	0	0	0	0
Oregon [OR]	1,219	337	48%	52%	0%	0%	0%	100%	60	160	582	6	0	0	0	1	637	331
Pennsylvania [PA][A,D]	6,825	11,837	33%	50%	17%	87%	< 1%	13%	253	481	2,283	< 1	1	1,149	4,360	7	3,393	8,357
Rhode Island [RI]	463	1	100%	0%	0%	100%	0%	0%	17	32	463	1	0	0	0	0	0	0
South Carolina [SC]	8,089	2,764	69%	30%	1%	> 99%	0%	< 1%	67	133	5,537	104	1	85	5	4	2,467	2,675
South Dakota [SD]	< 1	< 1	100%	0%	0%	100%	0%	0%	18	24	< 1	< 1	0	0	0	0	0	0
Tennessee [TE]	1,131	56	100%	0%	0%	95%	< 1%	2%	187	270	1,131	56	0	0	0	0	0	0

State	Disposal of at[b] Commercial Facilities		Percentage[b] By Source			Percentage[b] By Facility			Institutional[e] and Industrial				Government and[f,g] Military (Navy)			Commercial Power[h] Reactors		
	Total Volume [m³]	Total Radioactivity [Ci]	Institutional and Industrial %	Commercial Power Reactors %	Government and Military (Navy) %	Barnwell, S.C.	Beatty, Nev.	Richland, Wash.	Institutional[c] Licensees	Industrial[c] Licensees	Estimated[d] Volume [m³]	Estimated[d] Radioactivity [Ci]	Number of Installations	Volume [m³]	Radioactivity [Ci]	Number of Installations	Total Volume [m³]	Total Radioactivity [Ci]
Texas [TX]	543	410	100%	0%	0%	38%	62%	< 1%	605	982	543	410	0	0	0	0	0	0
Utah [UT]	106	9	100%	0%	0%	1%	54%	45%	17	83	106	9	0	0	0	0	0	0
Vermont [VT][A]	370	918	27%	73%	0%	100%	0%	0%	15	24	100	< 1	0	0	0	1	270	99[illegible]
Virginia [VA]	4,230	9,314	25%	72%	3%	99%	0%	1%	93	104	1,091	8,004	2	104	9	3	3,035	1,301
Washington [WA]	779	278	89%	0%	11%	< 1%	0%	> 99%	119	238	694	275	1	85	3	0	0	0
West Virginia [WV]	40	41	100%	0%	0%	94%	0%	6%	40	120	40	41	0	0	0	0	0	0
Wisconsin [WI]	487	3,058	9%	91%	0%	97%	0%	3%	98	166	42	1,359	0	0	0	4	445	1,699
Wyoming [WY]	< 1	< 1	100%	0%	0%	100%	0%	0%	17	59	< 1	< 1	0	0	0	0	0	0
District of Columbia	33	333	100%	0%	0%	100%	0%	0%	28	62	33	333	0	0	0	0	0	0
U.S. Totals	79,914	477,437	41%	50%	9%	79%	8%	13%	6,415	10,961	32,835	329,466	21	7,311	54,566	72	39,768	93,405

*Table compilations from NUS data.

NOTES:

[a]Table compilations constructed from [NUS Corporation] The 1979 State-by-State Assessment of Low-Level Radioactive Wastes Shipped to Commercial Burial Grounds, (November) 1980.

[b]Based on commercial burial ground facility records for 1979:
- Chem-Nuclear, Inc., records of waste receipts by state for 1979 for Barnwell, South Carolina.
- Nuclear Engineering Co., records for waste receipts by state for 1979 for Beatty, Nevada, and Richland, Washington.

[c]Based on U.S. Nuclear Regulatory Commission (NRC) records for 1979.

[d]NUS obtained a significant portion of this data by extrapolation or estimation from secondary sources. This was necessitated by the lack of a qualitative report in the public domain on the volumes and activities from industrial and institutional sources (the unquantified 1979 portion of the low-level waste volume amounts to 41% by volume and 79% by activity). For those wastes not fully characterized by such reports, the remaining volume was spread over the nation generally in proportion to the population of Agreement States and non-Agreement States to the national population. The waste was then further apportioned to each state on the basis of the ratio of state population to total Agreement State population for the Agreement States and by the ratio of the number of state licensees to the total NRC industrial licensees for the non-Agreement States.

[e]Data from the Army and Air Force commands do not constitute a significant volume of radioactivity source and are not reported separately under "Government and Military". Data is included under this section of the report.

[f]Only U.S. Navy data included, see footnote "e" also. P. D. Rice and G. L. Sjoblom, Environmental Monitoring and Disposal of Radioactive Wastes from U.S. Naval Nuclear Powered Ships and Their Support Facilities, 1979 Report NT-80-1, Nuclear Power Directorate. Naval Sea Systems Command, U.S. Department of the Navy, Washington, D.C., March 1980.

[g]U.S. Department of Energy, Solid Waste Information Management Systems (SWIMS) - Actual Solid Wastes Generated for Fiscal Year 1979, run date 02/22/80.

[h]NUS Summary information on commercial nuclear power plant wastes was obtained from semi-annual reports submitted to the NRC in accordance with NRC Regulatory Guide 1.21. Where reported data was not available, information was obtained by communication with the utility.
- Title 10, Part 50, Code of Federal Regulations, "Domestic Licensing of Production and Utilization Facilities", paragraph 50.36a.
- U.S. Nuclear Regulatory Commission, Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light Water Cooled Nuclear Power Plants, Regulatory Guide 1.21, Revision 1, June 1974.

[A]Differences in commercial power reactor records and commercial burial ground records may be attributed to a) rounding by both the reactor facility operator and burial ground facility operator, or b) there may have been waste that was in transit at the end of the year.

[B]Curie value (Ci) in institutional/industrial sector records may reflect the fact there were other sources of waste from the state. Propriety record agreements prohibit a further breakdown of available data.

[C]Liquid commercial power plant waste shipped out-of-state for processing may not be reflected in figures.

[D]For some states, the amount of waste which is in the institutional/industrial category may not represent the actual volume generated by firms in that state. Burial ground records list volumes from broker companies by the state of the home office (companies which collect material from several states and repackage or consolidate shipments under one radioactive shipping record).

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