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SCOPING SURVEY OF PERCEIVED CONCERNS, ISSUES, AND PROBLEMS
FOR NEAR-SURFACE DISPOSAL OF FUSRAP WASTE

by

John E. Robinson and Thomas L. Gilbert
Division of Environmental Impact Studies

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PREFACE

This survey was undertaken to provide the Formerly Utilized Sites Remedial Action Program (FUSRAP) with a timely scoping of issues for the development of the NEPA assessment methodology for the land disposal of FUSRAP wastes, analogous to the scoping process for an EIS. Information accessible during the period allotted to the literature survey focused mainly on low-level waste (LLW) concerns; extensive information was also available on uranium mill tailings. Particular attention centered on the licensing procedures, performance objectives, and technical criteria recently proposed (10 CFR 61) by the U.S. Nuclear Regulatory Commission (NRC) for near-surface disposal of commercial LLW, and on the still more recently issued Draft Environmental Impact Statement and Data Base for Management of Radioactive Waste, prepared for support of the proposed rules. The very large body of concerns and perceived problems that are common to both LLW and FUSRAP are covered in this report.

Since completion of the draft report, new issues and additional alternatives for FUSRAP have emerged that were neither covered in the literature nor apparent earlier. From study of the above NRC documents and from considerations specific to FUSRAP it appears that the 10 CFR 61 proposed rules are not appropriate to the FUSRAP because:

- Disposal in a near-surface facility cannot ensure isolation of various radionuclides important in FUSRAP wastes for the great length of time over which they may remain hazardous.
- The concentrations of radionuclides in FUSRAP wastes are much less than in commercial LLW (by factors of 100 or more).

In addition, it does not appear appropriate to commit as large a volume of LLW disposal capacity to FUSRAP wastes as would be required. The technical material required to expand the survey enough to cover the new foci of concern is still being developed. However, just as issues for LLW management are affected by prior general attention to high-level waste, FUSRAP planning and implementation may be complicated by current attention to LLW. This report therefore affords an overview of general experience and perceptions that may have to be dealt with.

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1. INTRODUCTION

This report is a scoping summary of concerns, issues, and perceived problems for near-surface disposal* of radioactive waste, based on a survey of the current literature. Proposed solutions to anticipated problems also are discussed. The purpose of the report is to provide a better basis for identifying and evaluating the environmental impacts and related factors that must be analyzed and compared in assessing candidate near-surface disposal sites for FUSRAP waste.**

Literature on low-level waste and related topics that has appeared during the past five years was reviewed. Several sources were used: searches of the DOE Energy Information Data Base using the DOE RECON system at Oak Ridge National Laboratory, published bibliographies (Fore et al. 1978; Fore et al. 1980; Blaylock and Fore 1980, 1981; Schilling and Keen 1980; USDOE 1980a); the Federal Register; and miscellaneous sources. Approximately 2000 references were screened by title, abstract, and cursory examination of the text. From these 2000, a list of nearly 75 major references was generated (Sec. 4). The major references represent a cross section of different concerns. Although the emphasis is on technical studies, the references also include material from public comments on studies used as a basis for writing regulations and from public-interest articles.

To prepare a summary of the broad and varied range of topics covered in the major references, a multistep approach was used. This approach was needed to permit preparation of a usable summary that retained the many detailed concerns that may require attention in the analysis of environmental impacts.

* Near-surface disposal means land burial in or within 15-20 m of the earth's surface. It includes shallow land burial (burial in trenches, typically about 6 m deep with a 2-m cap and cover) and some intermediate-depth land burial (e.g., trenches and cap similar to shallow land burial, but placed below 10-15 m of clean soil).

** FUSRAP wastes are of diverse types, and their classification for regulatory purposes is not yet fixed. Most of it may be characterized as "low-activity bulk solid waste", and is similar to mill tailings, but with somewhat lower average specific activity. It may also qualify as Class A segregated waste under the proposed 10 CFR 61 rules, but the parent radionuclides of concern in FUSRAP (primarily U-238 and Th-232) have longer half-lives than do the radionuclides of concern in most low-level waste. Most of the references reviewed deal with low-level waste or mill tailings, since there is as yet very little literature in the public domain on FUSRAP per se.

- The first step was to extract statements from the references in the form of questions, quoted text, and/or short summaries of concerns, issues, and perceived problems. More than 1000 statements were recorded. These summary statements preserve much of the complexity and detail of the topics covered.
- In the second step, the statements were categorized to facilitate preparation of an outline that could be used to identify the major areas of common concern. Several outlines were considered, including EIS outlines and categorizations proposed in the references. There is no unique or well-defined procedure for selecting categories; the outline that evolved was designed to minimize the number of major categories and the number of statements that were not categorizable or pertained to all or most categories. Since no predetermined outline was used during this evolutionary process, the outline developed differs from an EIS outline and from outlines used in previous studies.
- Next, the statements were entered into a computer data base and assigned codes corresponding to one or more categories of the outline. This was done to simplify the process of making subsequent changes in the categories and assignments to categories, and to facilitate the addition of statements and the printout of updated, categorized lists of the statements. A current listing of all of the statements, organized into categories, is given in Appendix A.
- In the final step, a brief summary of the concerns, issues, and problems in each category was prepared, based on the statements in the category. Discussions of some proposed solutions are included. These individual summaries constitute the main body of the report, and are presented as Section 2.

One of the objectives of this survey was to provide an indication of the level of interest in different topics of concern. A tally of the number of statements in different categories and subcategories was indispensable for this purpose. The following caveat regarding the interpretation of the tallies is in order.

The references selected represent the best information presently available regarding concerns, issues, and problems related to near-surface disposal of low-level radioactive waste. The references were not selected by a scientific sampling of a well-defined group or body of opinion, and the process of extracting summary statements from the references is not well-defined and accurately reproducible. Subjective factors entered into the statement extraction process--for example, the authors tended to avoid excessive repetition and to emphasize material that was concisely presented and readily quoted or summarized. If this survey were repeated by others, the list of major references selected, the categories used, the statements extracted, and the tallies would undoubtedly be somewhat different. However, it is believed that if a reasonable effort were made to obtain a broad cross section of the available literature and to avoid any conscious bias, the identification of major issues and problems, as presented in Sections 2 and 3, would be essentially the same.

The list of references (Sec. 3) includes all of the references that have been reviewed. Not all of the references have been abstracted (in the form of statements included in Appendix A) and summarized. The statement list is sufficiently complete to meet the scoping objectives of this draft report. The data base for this survey is organized in such a manner that additional references, statements, and categories can be added and incorporated into the summaries at a later time.

2. CONCERNS, ISSUES, AND PROBLEMS IDENTIFIED IN RECENT LITERATURE

The major categories used for organizing the stated concerns, issues, and problems are listed in Table 2.1 together with a tally of the number of statements classified in each category. Descriptions of the scope for each category and summary discussions of the topics covered by the statements in each category are given below.

In referring to specific statements, which are listed in Appendix A, the following conventions are used. The statements in Appendix A are numbered sequentially within each category and subcategory. The categories and subcategories in Appendix A correspond to the second- and third-order headings of this section; e.g., statements listed in part A.3.2 of Appendix A are summarized in Section 2.3.2. If in this section reference is made to a statement in the corresponding section of Appendix A, only the sequence number of the statement is given. If reference is made to a statement in another section of Appendix A, the Appendix A section number is given, followed by a diagonal and the statement number in parentheses. For example, if a reference to Statement 19 of Category A.1.1 is made in Section 2.1.1, then it is given as (19); if a reference is made in any other section, it is given as (A.1.1/19).

2.1 INSTITUTIONAL

This section contains statements referring to extant or potential laws, regulations, and political processes that may affect FUSRAP land disposal technological tasks. Regulations applicable to FUSRAP wastes have not yet been proposed (see, however, USNRC 1981d), and, for many FUSRAP sites, authority for DOE to act has not been established. The evolution of regional compacts clearly constitutes a new and major factor in radioactive waste disposal but the relationship between compact development and FUSRAP has not yet been discussed in the literature. Aside from these and a few other points indicated later, the institutional concerns conveyed by the statements are those that arise in regard to mill tailings and low-level waste (LLW) disposal.

In terms of major disposal actions or phases, issues revolve about (1) input to and control over the site selection and licensing process; (2) who should operate the site and monitor its performance; and (3) who should be responsible for post-closure functions. Site ownership and assurance of adequate financing for long-term care are seen to be important. Two ancillary concerns are pervasive. The first, accountability to the public, is exemplified by the almost ritualistic mention of public or local review, comment, and involvement. The second, stability and adaptability, is reflected in numerous statements regarding institutional controls and interactions. A third, economic efficiency, while implicit in many of the statements, is more explicitly prominent elsewhere (see Section 2.4.3, Economic Costs).

Table 2.1. Number of Statements and Percent of Total in Each Major Category of Perceived Concerns, Issues, and Problems

Category	Statements† ¹	
	No.	% of Total
Releases and Their Consequences (A.2)† ²	300	15%
Socioeconomics (A.4)	216	13%
Institutional (A.1)	209	13%
The Natural Environment (A.3)	197	12%
Facility Engineering (A.6)	166	10%
Facility Management (A.5)	164	10%
Risk and Uncertainty (A.7)	140	8%
Waste (A.8)	129	8%
Site Selection (A.10)	59	4%
Other Land Disposal Options (A.11)	47	3%
Transportation (A.9)	27	2%
	1660	

†¹ The number of statements (1042) is less than the total count because many statements were classified in more than one category.

†² The corresponding section of Appendix A is given in parentheses for each category listed.

2.1.1 Federal Laws and Rulemaking

The focus in this subsection is on what items or functions should be covered by federal statute or regulation, either directly or as minimum requirements. The emphasis is more on rulemaking criteria than on quantitative standards. Statements related to specific standards generally have been placed under the category of the item or function regulated, although many are to be found here as well (e.g., 90 and A.2.2/75). Questions and comments regarding the applicability of federal rules, assumption of responsibility by federal agencies (e.g., 52-60), and related difficulties (e.g., 82) also are collected here.

Common concerns and a partial listing of the statements pertaining to them include long-term care and risks (17, 20, 21, 26, 31, 39, 46, 47, 77, 81, 86); radiation doses and releases (22, 26, 32, 34, 48, 49, 86); costs, etc. (11, 30, 31, 43, 50); and radiation worker protection (32 to 37). Less familiar concerns are environmental release of solids (44, 54, 67, 68, 69) and chemical and other non-radiological hazards (72, 92, 96, 115, 120). Sets of statements pertain to mill tailings (76-81, 85-88) and to FUSRAP (56-60). A sizeable number of statements extracted from the proposed LLW rules (10 CFR 61) is

included to provide an overview of the most recent pertinent regulations (89-118). There appears to be a general trend in regulation toward emphasis on performance objectives rather than detailed prescription, and toward greater flexibility (89, 112).

2.1.2 State, Local, and Federal Conflicts; Regional Issues

The most widely recognized issues are those raised by state and local resistance to importation of waste and establishment of new disposal sites (22, 42, 49). Whatever the effect of the commerce clause or preemption, serious political problems are involved (51, 53, 55). Perhaps the most significant new factor is the formation of regional compacts (19, 22, 23, 24, 33, 41, 46). In every issue of the last year's State Legislature Information bulletins circulated by NRC's Office of State Programs there is at least one newly enacted or proposed compact-related statute. Statements explicitly referring to FUSRAP are 18, and 26 through 32. Constraints imposed on states and options open to them can affect all phases of radwaste disposal (8, 9, 13, 14, 16, 40, 36, 48). The mix of control and responsibility chosen by a state is strongly conditioned by availability of suitable sites, expertise, and resources. An extreme example of conflicting authority and interest is included (56).

2.1.3 General Legal, Regulatory, and Philosophical Issues

The statements in this subsection are sufficiently few and diverse that it is easier to read them directly than to follow a guide to them. Those that refer explicitly to FUSRAP are 11, 13 through 15, and 25.

2.2 RELEASES AND THEIR CONSEQUENCES

Near-surface disposal is intended to isolate radioactive waste from the environment. Concerns related to the effectiveness of containment and the consequences of releases are a dominant theme. Many of the concerns expressed in other areas (e.g., institutional controls, facility design and management, site selection) are, indirectly, containment and release concerns. The statements summarized in this subsection are those that deal directly with the mechanisms that lead to releases; the dispersal of hazardous constituents; and the consequences of human exposure to the releases. Nearly all of the statements deal with releases of radioactivity and the consequences thereof; a very few relate to toxic substances.

The statements have been separated into two broad subcategories: those referring to release mechanisms and dispersion (68%) and those dealing with health effects (32%).

2.2.1 Release Mechanisms and Dispersion

A waste-related adverse health effect starts with release of a hazardous substance from the disposal site and is followed by dispersion through one or more pathways to human exposure at some point along the path. The various mechanisms by which releases can occur can be classified into eight types, as indicated by the small boxes in Figure 2.1. The possible pathways are rather complex and cannot readily be enumerated by a simple classification scheme. A representation of some of the pathways that can occur is shown in Figure 2.2. Statements that relate to dispersion through the pathways or to releases and

Fig. 2.1. Mechanisms for Release of Hazardous Constituents from Buried Low-Level Waste

Fig. 2.2. Potential Exposure Pathways for Buried Low-Level Waste.
From Murphy and Holter (1980, p. 8-9).

dispersion by means of several release mechanisms (33% of the statements relating to release mechanisms and dispersion) are summarized in the following paragraph.

The need for additional studies to provide a better basis for release predictions (5, 22-25, 27 29-31, 48, 50, 63) and comments and questions regarding the adequacy or validity of the models used for release and/or dispersion predictions (14, 19, 49, 66) are recurrent themes. These concerns all point to the pervasive problem of lack of knowledge; no solutions to this problem other than recommendations for a continued research effort are proposed. A number of statements identify the various pathways and exposure mechanisms (11, 17, 18, 28, 35, 36, 46, 47, 51, 54, 58), and some of the statements on specific models and methods of analysis (20, 21, 41, 42, 59) suggest methods for estimating the releases and pathway dispersion. There are also a number of statements on the effectiveness of human-provided barriers and the need for engineered barriers (3, 6, 9, 32, 60). No reliance is placed on barriers provided by containers; natural barriers are regarded as the primary means of containment, especially for the long term. Dilution and dispersion is mentioned as a means of disposal (15). A number of specific site/waste stabilization techniques for controlling radionuclide release and transport following decommissioning of a low-level waste (LLW) burial ground are proposed and rated for effectiveness (61, 62). Several statements express concern regarding long-term isolation (10, 43, 44, 50, 52, 57), but the meaning of "long-term" is not clearly defined in any of the references, and no solutions that directly address the problem of isolation by near-surface disposal for long times (over 1000 years) are proposed. A number of statements recommend intermediate-depth land burial as a more effective and longer-term means for isolating the waste (8, 13, 37-40). Several statements are general admonitions (1, 2, 4, 10, 26), and some are clarifying comments (7, 34, 53).

Statements referring specifically to individual release mechanisms constitute 46% of the statements on releases and their consequences and 67% of the statements on release mechanisms and dispersion. The distribution of these statements among the different types of release mechanisms (Table 2.2) provides a rough indication of the level of concern for different mechanisms. It is clear that leaching is the mechanism that is perceived to be of dominant concern.

2.2.1.1 Leaching to Surface- and Groundwater

The complexity of the hydrogeologic processes that lead to leaching, concerns regarding the validity and reliability of predictions, and the need for more information and better models are the dominant recurring themes that provide an overall characterization of the statements related to the leaching problem. Many statements are direct expressions of concern regarding the reliability of predictions (3, 5-14, 16, 19, 67). Others express this concern in a more focussed manner by identifying major issues and problems and suggesting research priorities and areas that need further study (29-32, 42, 43, 49-52, 57, 58, 68). The diverse mechanisms that must be taken into account are identified (17, 20, 40, 41, 44-48, 53-56, 59), and methodologies and models for predicting the leaching rate under the many different conditions that can occur are suggested (18, 22, 24-28, 33-35, 60, 61). Models that will predict water migration and radionuclide transport in fairly complex geometries and multilayered strata exist; however, the models may not be adequate and, in

Table 2.2. Number of Statements and Percent of Total in the Subcategory of Different Types of Release Mechanisms

Type	Statements	
	No.	% of Total
Leaching to Surface- and Groundwater (A.2.1.1) ^{†1}	70	51%
Diffusion of Gases (Primarily Radon) (A.2.1.2)	20	15%
Human Intrusion (A.2.1.4)	18	13%
Erosion and Windblown Dispersion (A.2.1.3)	10	7%
Plant Uptake (A.2.1.5)	9	7%
Burrowing Animals (A.2.1.6)	5	4%
Catastrophic Events (A.2.1.8)	3	2%
Direct Radiation (A.2.1.7)	<u>2</u>	1%
	137	

^{†1} The corresponding subsection of Appendix A is given in parentheses for each category listed.

particular, the data may be lacking to take into account such complexities as enhanced migration due to formation of complexes with other compounds (including chelates); microbial actions in the soil, fissures, precipitation and filtration; a variety of chemical and physical adsorption mechanisms and chemical reactions; vapor transport, etc. There appears to be no known solution to the problem of making more reliable predictions applicable to field conditions. The only proposed solutions to the leaching problem that avoid the uncertainties in leach rate predictions are to prevent or avoid infiltration of water into the waste (62, 64-67) and to provide an adequate buffer zone and monitoring capabilities for detecting and controlling radionuclide migration (39).

2.2.1.2 Diffusion of Gases (Primarily Radon-222)

Many of the statements are simple expressions of concern regarding radon emissions (7, 12, 20), questions regarding predictability (2-6, 8), and identification of areas needing further study (14, 16). If the standards for mill tailings are applied, the release rate will be limited to 2 pCi/m²/sec. Some statements identify the mechanisms and pathways (9, 11, 13, 15). The proposed solutions for controlling the emission rate are use of sufficient earth cover (not less than 3 meters) (17), and deeper burial (10). It is pointed out that techniques that control radon releases reasonably well reduce airborne particles and direct gamma radiation to negligible levels (19).

2.2.1.3 Erosion and Windblown Dispersion

The dominant theme, expressed in essentially all of the statements regarding erosion, is that erosion is a major concern. Examples of problems at existing sites are given (3, 4), and the effects of erosion on other release mechanisms (5, 7, 8, 9) are noted. The importance of erosion in assessing long-term isolation (e.g., several millenia) is noted (6). The statements

recorded do not include detailed suggestions for controlling erosion; the use of riprap for controlling wind erosion and contouring and careful choice of vegetative covering for controlling water erosion has been suggested, and is mandated for mill tailings (A.6.2/10).

2.2.1.4 Human Intrusion

About half of the statements regarding human intrusion are expressions of general concern emphasizing the perceived importance of the problem of human intrusion (1, 2, 6, 10, 14, 15). Deeper burial is perceived as a means of managing the problem (3, 4, 8, 9, 13). Another suggestion is to render the waste unattractive to a potential reclaimer (7). Intrusion scenarios for bounding estimates of health impacts are prominent (16-18, and A.2.1/65).

2.2.1.5 Plant Uptake

All of the statements on plant uptake note its importance as a potential release mechanism. Three statements (2, 3, 4) give specific examples of plant uptake by deep-rooted plants. Intermediate-depth land burial is suggested as a means of control (7).

2.2.1.6 Burrowing Animals

The statements on burrowing animals bring attention to the problem; the use of intermediate-depth burial (4) and rock layers (5) are suggested as a means of control.

2.2.1.7 Direct Radiation

The problem is noted, with the suggestion that direct gamma exposure be reduced to background levels (1), and it is pointed out that measures to control radon releases provide complete control of direct gamma radiation (2).

2.2.1.8 Catastrophic Events

Natural disasters, catastrophic storms, and tectonic events are mentioned in this category as matters that should be taken into account; no mitigation or avoidance measures are suggested.

2.2.2 Health Effects (Radiological Consequences)

The two areas that receive the most attention are methodology for assessing health effects (6, 7, 10, 14-23, 25, 27, 38, 39, 48, 51, 53-57, 83, 85) and standards and criteria (1, 2, 12, 13, 24, 28-30, 32-34, 41-43, 71, 72, 74-79, 84, 86, 87, 89-90). The question of whether health risks should be characterized by the annual dose or integrated dose is a recurrent theme. The need for establishing de minimus thresholds below which the hazards are negligible is pointed out (29), and the question of the appropriate magnitude for such thresholds is raised in several statements (24, 34, 43, 71, 74, 92). There are a number of general comments on the health hazards: some are merely admonitions (3, 4, 11, 26); some make the point that the impacts may be expected to be small (46, 58, 61); a number deal with the problem of identifying and quantifying the health hazards (49, 50, 52, 59, 60, 62-64, 70, 71, 73, 93, 94), and some are general concerns (8, 9, 31, 36, 37). Almost all are concerned with the radiological hazards from ingestion, inhalation or direct

exposure to radioactive materials, but the issue of chemical toxicity is raised (44, 47). Mitigation measures are discussed (40, 65-68); all are proposals for controlling releases and/or exposure. These means are discussed in greater detail in other categories (see, for example, Sec. 2.1). The time periods of concern are noted (5, 81, 82), but none of the statements consider time periods beyond 1000 years. Exposure/dose relations and mechanisms by which exposure leads to health effects are important to setting criteria, but are independent of disposal alternatives. They constitute a large topic more appropriately addressed elsewhere and are not covered in the references selected.

2.3 THE NATURAL ENVIRONMENT

Statements related to the natural environment of a near-surface burial site are primarily concerns regarding the influence of the natural physical environment on containment effectiveness rather than concerns regarding the effects (other than human health effects) on the physical and biological environment. Most concerns relate to the effect of the physical environment on containment (Secs. 2.3.1-2.3.4; Appendix A.3.1-A.3.4); a very few biological effects are considered in Section 2.3.5 (Appendix A.3.5). The distribution of statements among the environmental categories is shown in Table 2.3. The categories that receive the most attention are hydrology and geology. The distinction between these two categories is somewhat blurred and arbitrary; statements dealing with movement and contamination of surface- and groundwater (primarily the latter) have been classified under hydrology; those dealing with topography and underlying strata, under geology. The first two categories, together, constitute a more clearly delineated category of hydrogeology.

Table 2.3. Number of Statements and Percent of Total
in Subcategories Related to the
Natural Environment

Category	Statements	
	No.	% of Total
Hydrology (A.3.1)† ¹	102	55%
Geology (A.3.2)	42	23%
Meteorology and Climate (A.3.4)	21	11%
Ecology (A.3.5)	13	7%
Seismology and Volcanology (A.3.3)	8	4%
	186	

†¹ The corresponding section of Appendix A is given in parentheses for each category listed.

Statements related to the natural environment that are not classifiable in a specific environmental category (the first 10 statements in Section A.3.1) are primarily concerned with overall requirements for characterizing and selecting a site (2, 3, 5, 6, 7, 9, 10). Some also are concerned with potential problems due to changes in the environment (4, 8, 9).

2.3.1 Hydrology

Hydrological standards and criteria for acceptable disposal sites receive considerable attention (1-6, 9, 10, 15, 16, 89-98). The central concern is to keep out water. The requirements therefore include proscriptions on areas subject to flooding, and emphasis on good drainage, adequate distance between waste and water table, and performance standards for maintaining groundwater quality. Considerable concern is expressed regarding the reliability of predictions regarding groundwater movement and radionuclide migration (21-28, 30, 66). The questions of whether one can even achieve order-of-magnitude reliability (27) and the feasibility of simplified approaches (26) (which have the merit of being easier to understand and check for errors) are raised. A number of statements point out the problems of acquiring adequate data for site characterization and modeling (38, 40, 50, 51, 61, 62, 64, 65, 69). The need for field data in addition to laboratory data is emphasized (51, 73). The sorptive characteristics of the surrounding strata are especially important; many complex factors are involved (fissures, precipitation, filtration, surface reactions, etc.); these complicate the problem of defining sorption coefficients that can be used for modeling (61, 62, 65). The effect of other chemicals and also microorganisms that may be present must be taken into account (39, 78, 79). The many other factors that must also be taken into account in predicting site performance are identified (42-47, 82-85). The usefulness of modeling for specific questions, such as monitoring of well placement (41), is noted, but no suggestions are given for solving the problem of acquiring sufficient data and understanding of the mechanisms to permit reliable modelling, other than more research (67, 68). Proposed solutions for the potential hydro-geological problems (32, 34, 53, 54, 57, 59) include deeper burial (33), design improvements (58, 69, 71) and, primarily, keeping out the water (55, 58, 86, 88). A recent systems analysis suggests that impacts may be less sensitive to nuclide solubilities and dispersion coefficients than has been thought (41, 42).

2.3.2 Geology

The dominant geological concerns are erosion (4, 9, 17, 18-21, 25-27, 29, 30, 35, 37, 38) and soil properties (5, 7, 13-16, 22, 32-34, 39). One analysis estimated exposure of a shallow land burial site by sheet erosion would occur in 2,000 to 13,000 years (30). Deeper burial is a solution for increasing this time (23). Emplacement in former strip mines also is suggested (24). Statements regarding soil properties are almost all concerned with the sorptive characteristics of the soil for radionuclides. The need to avoid areas with valuable subsurface minerals is noted (36). Modeling problems, with emphasis on uncertainties due to fractures in underlying strata, are noted (8, 10, 31).

2.3.3 Seismology and Volcanology

The thrust of statements in this category is the need to avoid areas where tectonic processes might jeopardize performance objectives or preclude

defensible modeling (6, 7, 8); a number of question regarding the seismic standards also are raised (1-5).

2.3.4 Meteorology and Climate

The primary meteorological concern is the need to anticipate the consequences of severe weather and catastrophic storms (9, 12, 13, 15) and to avoid areas with severe climatic conditions that could adversely affect containment (7, 8). A concern regarding air quality is expressed (1, 2). The desirability of siting in areas of low precipitation (16) and choosing a site with good wind protection (20) are noted. Some effects of climate on site performance are noted (8, 10, 11, 14), including effects mediated by microorganisms (10). The use of shields and movable structures to mitigate the effects of precipitation during trench filling is suggested (17, 18).

2.3.5 Ecology

With one exception (which deals with hazardous chemical criteria (2)), all statements relate to terrestrial ecology. Some concern is expressed about impacts of site operation on the ecology (1, 9,), but there is greater emphasis on the impacts of ecological origin on site operation; e.g., plant and animal intrusion (3, 4, 10) and microorganisms (6, 7, 8). These matters are covered in more detail in Sections 2.2.1.5 and 2.2.1.6.

2.4 SOCIOECONOMICS

Statements classified under socioeconomics are dominated by economic costs (39%), public concerns (38%), and land use (17%). Their distribution among subcategories is given in Table 2.4.

Table 2.4. Number of Statements and Percent of Total in Each Subcategory Relating to Socioeconomics

Category	Statements	
	No.	% of total
Economic Costs (A.4.3)† ¹	83	39%
Public Concerns and Perceptions (A.4.6)	81	38%
Land Use (A.4.4)	36	17%
Demography (A.4.2)	8	4%
Cultural Resources (A.4.1)	4	2%
Noise (A.4.5)	<u>1</u>	
	152	

†¹ The corresponding subsection of Appendix A is given in parentheses for each category listed.

2.4.1 Cultural Resources

Aside from obvious generalities, two instructive case histories are summarized (3, 4).

2.4.2 Demography

Only a few statements relating to demography were found; these can be read quickly, and no comment is required here.

2.4.3 Economic Costs

Nearly everyone agrees that costs, benefits, and risks should be analyzed. The general issues arise with regard to comparisons and tradeoffs, choice of a numéraire (3, 16, and A.4.3.4/1). All give priority to safety as compared to cost (1, 14, 19, 21), but the most conservative possible assumptions may not be reasonable policy (23). The specific issues placed in A.4.3.1 include costs of analysis and data acquisition (A.4.3.1/2 to 5), transportation (A.4.3.1/9), and provision for long-term safety (A.4.3.1/12 to 15). One statement quite pertinent to FUSRAP is very critical of relocation of waste originally buried without intent of retrieval (A.4.3.1/13), and another raises the issue of dispersal versus containment (A.4.3.1/18).

The prescriptive comments in (A.4.3.2) contain specification of the input required for a cost-benefit approach to radioactive emission control (A.4.3.2/9), and the conclusion that such would be impracticable for setting limits on radon flux from mill tailings. The statements regarding liabilities (A.4.3.3) show a preference for payment of disposal costs by generators and beneficiaries. Under specific estimates and comparisons (A.4.3.4) are several statements concerning assumptions that have been used (A.4.3.4/2, 7, 8, 11, 13, 14) and several results better read directly than summarized here.

2.4.4 Land Use

The statements collected here include a list of factors to be considered (A.4.4/26), prescriptions directed toward avoiding problems (A.4.4/13, 14, 27, 28, 29), and decommissioning options (A.4.4/30 to 33). The possibility of using strip mines for LLW disposal is mentioned (A.4.4/7, 10, 21, 22). Two case histories of reclamation are included (34, 35).

2.4.5 Noise

No statement of substance relating to noise was found.

2.4.6 Public Concerns and Perceptions

Historically, high-level waste and nuclear power plants have figured more prominently than LLW in shaping public concerns and perceptions. The appearance of serious articles for the nonexpert (see, for example, Shapiro 1981) and of partisan environmentalist programs (see, for example, The Waste Paper, 1981a and 1981b) may signal some shift of attention toward LLW disposal. In any event, presentation to the public of LLW issues is likely to remain complicated by potential confusion with high-level waste (HLW). In turn, presentation of FUSRAP issues will have to deal with prior public awareness of commercial LLW and mill tailings issues.

Some statements simply mention public review (1, 12, 14, 32); a few list possibilities for informing or involving the public (4, 20, 26) or emphasize the importance of public acceptance (8, 19, 45). A pertinent review of types of hearings, public inquiries, advisory councils, study groups, and information forums that have been held in Europe and the U.S. and analysis of their effectiveness has been given by Nelkin and Pollack (1980). Several statements touch on aspects of public perceptions (22, 25, 31, 33, 36, 37, 42, 43), and public comments on uranium milling are summarized in 38 and 39. Regarding inexperience in assessing risks (33), the factors affecting perception of risk are more numerous and complicated than in the common technological formula for risk, i.e., probability times consequence (see, for example, Slovic et al. 1980). The specific examples given in A.4.6.1 are more easily read directly than summarized here. Those taken from Shapiro (1981) will have had significant circulation, and some of these refer directly to FUSRAP (20-23).

2.5 FACILITY MANAGEMENT

Facility management includes all planning, supervisory, and operational activities involved in receiving, monitoring, and recording incoming waste; placing the waste in trenches; opening, filling, and closing and sealing the trenches; monitoring the releases; and related activities. Management extends from a short time before the site is opened until the site is decommissioned.

Seven subcategories are used for organizing and summarizing the statements related to management; the distribution of statements among these subcategories is given in Table 2.5. Statements not belonging to the subcategories may be summarized as follows.

Table 2.5. Number of Statements and Percent of Total in Each Subcategory Relating to Facility Management

Category	Statements	
	No.	% of total
Closure, Stabilization, and Long-Term Care (A.5.5) ^{†1}	31	23%
Waste Handling, Emplacement, Related Accidents (A.5.7)	23	17%
Monitoring Goals and Programs (A.5.1)	22	16%
Records, Documentation, and Reporting (A.5.3)	18	13%
Historical Problems - Examples (A.5.6)	18	13%
Performance Evaluation, Quality Assurance (A.5.4)	13	10%
Water Management Goals and Programs (A.5.2)	10	7%
	135	

^{†1} The corresponding subsection of Appendix A is given in parentheses for each category listed.

The question of retrievability and relocation is raised (4, 21, 24, 25), and cogent reasons for dismissing this option are given. The matter of decommissioning is raised; this is an important topic that has been the subject of a recent detailed study (Murphy and Holter 1980) that cannot be adequately summarized here or by means of a few statements (21-25). The need for controls is noted (2, 5), and a general list of controls not now in place is given (15). Two statements provide a check list of operating procedures (16, 17). Miscellaneous topics include interim storage needs (6, 10), the need for public openness (7), for a formal policy (13, 14), interim storage (6, 10), research topics (11), safeguards (9).

2.5.1 Monitoring Goals and Programs

The overall objective of a monitoring program is to establish the effectiveness of containment and obtain advance warning of any releases so that action can be taken before the releases become large enough to present a health hazard. Modeling based on a knowledge of the hydrogeological and meteorological characteristics of the site is needed in order to provide an adequate basis for monitoring provisions, e.g., well placement, precision and number of measurements, etc. Some statements merely reiterate the need and objectives (5, 13, 16, 19); others deal more specifically with the matter of providing an adequate basis for the design of a monitoring program (7-10, 14, 20, 21).

2.5.2 Water Management Goals and Programs

Water management is the single most important factor for controlling releases (A.3.1/55, 86). It is primarily a site-selection and engineering problem, but management practices related to procedures for installing liners, burial, cap placement, and trench sealing also are important. Experience at existing sites (3, 10) and the need to record and review experience at existing operations for subsequent use are pointed out (6). The primary goal is to prevent water infiltration (2; see also Secs. 2.2.1.1 and 2.3.1). Pumping is an effective but costly means; good cap and trench design and emplacement are preferable long-term cost-effective means (5). Monitoring to detect cap or liner deterioration is needed (9). Several statements point out the need to establish an appropriate balance between the conflicting requirements for erosion control and water infiltration control (4, 7, 8).

2.5.3 Records, Documentation, and Reporting

Most of the statements are concerned with identifying the topics that should be recorded and/or reported (1-10, 16-18). The inadequacies of existing records are noted (11, 14). The needs for standardization and verification (13) and for a tracking system (15) are pointed out.

2.5.4 Performance Evaluation, Quality Assurance

The need for monitoring radionuclide migration is a major theme (1, 6-10); in one statement there is emphasis on the need for identifying and monitoring pathways, not just the perimeter (9). Several statements point out the need to examine and review the many other factors involved, including management operations and procedures and the manner in which measurements are performed and interpreted (2-5, 11-13). It is pointed out that the problems that have occurred have resulted largely from lapses in good management practice;

the proposed solution is to establish management practice codes that cover all aspects of facility operation (11).

2.5.5 Closure, Stabilization and Long-Term Care

Several statements emphasize the importance of the objective of closing and stabilizing the site in such a manner that further active maintenance is unnecessary (9, 11, 14, 18, 23). The time for postoperational control should be minimized (10), and should not exceed about 5 years (16, 20). One statement lists the activities involved in long-term care (28), but the time period involved is not stated. Proposed LLW rules assume that Class A segregated waste and Class B stable waste will decay to levels that do not pose a danger to public health and safety in 100 years (18); long-term intrusion protection is therefore unnecessary; for Class C intruder waste the corresponding period is 500 years (A.2.2/82). A stated objective is eventual unrestricted use (11). Concern regarding the funding and financial responsibility for post-closure care has been expressed (15, 26).

2.5.6 Historical Problems - Examples

Historical problems include water infiltration (5), sagging of trench covers (6), trench cap erosion (7) increased (but nonhazardous) radioactivity in the site environs (8), liquids leaking from buried waste drums (10), miscellaneous technical problems (2), and assorted management or remedial problems (11-14).

2.5.7 Waste Handling, Emplacement, Related Accidents

The statements in this category are mostly suggestions for managing disposal operations. These suggestions include: segregate different types of waste (1, 2, 7, 16), restrict liquids (3, 4) and empty containers (5), automate operations (6), use orderly emplacement and utilize space effectively (11, 17, 18), use air-supported weather protection buildings to reduce dispersion and accidents (13, 14), minimize voids (18), and mark clearly (19, 20).

2.6 FACILITY ENGINEERING

Facility engineering is one of the three major areas of planning and action that must be carefully attended to in order to minimize releases and their consequences. (The other two are site selection and facility management; institutional controls may be regarded as the framework within which strategies for the three "theaters of action" must be developed.) The relevant engineering aspects have been divided into eight subcategories listed under the headings below; the distribution of statements among these subcategories is given in Table 2.6. General statements that do not fit into these categories may be summarized as follows.

Questions are raised regarding the relative importance of engineered vs. natural barriers (1, 2), and several statements express concerns related to the use or effectiveness of engineered barriers (11, 12, 23, 24). Lists of engineering problems are given (20, 21), the need to design for closure and minimum post-closure and long-term care (4-8, 28, 30) and control of gaseous emissions (9, 26) are pointed out, and the need for field-testing of designs (29) is noted. Lists of items to consider in facility specifications are

Table 2.6. Number of Statements and Percent of Total in Each Subcategory Relating to Facility Engineering

Category	Statements	
	No.	% of total
Water Management (A.6.1)† ¹	24	19%
Erosion and Intrusion Control (A.6.2)	20	16%
General Site Requirements and Desiderata (A.6.5)	20	16%
Burial Trenches (A.6.3)	19	15%
Waste Emplacement (A.6.4)	17	13%
Deeper Burial (A.6.7)	15	12%
Historical Examples (A.6.6)	7	5%
Retrievability (A.6.8)	6	5%
	128	

†¹ The corresponding subsection of Appendix A is given in parentheses for each category listed.

given (13, 14, 36, 37). Miscellaneous topics include a remark on the need to examine impacts from engineering changes during operation (16), comments on current practice (18, 19), instrumentation development (17), categories for analysis (31), site capacity (25), and definitions (32, 33).

2.6.1 Water Management

Design for water management is primarily concerned with control of surface drainage (1-8), and water infiltration (15, 17, 18, 24). The most effective control is by means of trench and cap design (4, 17, 20, 24). The cap should be less permeable than the liner to avoid the "bathtub effect" (4). A high slope, impermeable cap, and limited vegetation minimize infiltration but maximize erosion; parameters must be chosen to limit both, and some compromises may be necessary (17). Pumping reduces trench water, but is not cost-effective (18). A buffer zone and a monitoring system are needed for adequate control (9-11, 16).

2.6.2 Erosion and Intrusion Control

Erosion control measures include vegetative cover, contouring, gentle slopes, catchment areas, diversion channels, rock cover, and special materials and good maintenance for trench caps (6, 9, 10, 14, 17). Care must be taken to minimize water infiltration, also (4, 8). Protection against deep-rooted plants and burrowing animals is needed (7, 16); deeper burial and thicker covers are solutions (2, 13). Care must be taken to minimize voids in the emplaced waste (12).

2.6.3 Burial Trenches

Many statements are admonitions for careful trench design (1-6). Specific suggestions include soil compaction and injection of solidifying material (9), use of buffer zones (12, 19), coarse/fine sand layers (14), use of crushed rock, sand drainage ditches, proper inclination and pumping and processing (15), concrete liners (17), and impermeable bottom liners (18).

2.6.4 Waste Emplacement

Work automation (1), standardized packaging (4), movable weather shields or protective structures (7-9, 16, 17), compaction (5), and waste segregation (11) are among the waste emplacement suggestions. Concern is expressed regarding a possible explosion or fire (3).

2.6.5 General Site Requirements and Desiderata

Items mentioned include the need to rely on engineered and natural barriers rather than institutional control (1, 7), lists of problems and control techniques (2-6, 17, 18), general admonitions (8-11), stabilization planning suggestions (13, 14), decommissioning modes (15), a list of stabilization activities that include engineered water flow and erosion control, grouting or chemical injection, plant and animal control and physical barriers (16), and exclusion zones (19).

2.6.6 Historical Examples

Historical data are available for a number of sites, including the currently operating commercial sites at Hanford, WA, Beatty, NV, and Barnwell, SC; the recently closed commercial sites at Sheffield, IL, Maxey Flats, KY, and West Valley, NY; and a number of DOE sites. Statements in the references abstracted cover only limited aspects of a very few sites. The quite recently issued data base for 10 CFR 61 contains an extensive history of experience at LLW sites (USNRC 1981c).

2.6.7 Deeper Burial

The few statements in this category point out some advantages of intermediate-depth land burial (IDLB) as opposed to shallow land burial (SLB), and suggest the possibility of burial in old strip mines. One example IDLB facility is described (14).

2.6.8 Retrievability

Several statements dismiss retrievability as a reasonable option (1-3); one statement points out problems that were encountered in retrieving waste at INEL (4); one statement suggests engineered storage for waste that might require retrieval (5); and one statement asserts that low-level waste should be retrievable (6).

2.7 RISK AND UNCERTAINTY

Questions of risk and uncertainty in one form or another, implicit or explicit, may be identified in the issue statements under virtually every topical category and subcategory. It is intended that this section highlight some of the more generic problems in risk and uncertainty analysis. A few important aspects of these problems are identified by subcategories listed below, and the distribution of statements among these is given in Table 2.7. There is considerable overlap with other sections of the report, particularly with the section on public concerns and perceptions (Sec. 2.4.6; Appendix A.4.6).

Table 2.7. Number of Statements and Percent of Total in Each Subcategory Relating to Risk and Uncertainty

Category	Statements	
	No.	% of total
Assessment Uncertainties (A.7.1) ^{†1}	22	26%
Quantification:		
Risk Measures, Valuation, Comparisons (A.7.2)	23	27%
Specific Risk Statements (A.7.3)	19	23%
Long-Term Future (A.7.4)	20	24%
	84	

^{†1} The corresponding subsection of Appendix A is given in parentheses for each category listed.

Many statements are concerned with what should be included in a waste disposal risk assessment (7-17, 30, 35, 38, 39, 47), with an emphasis on completeness or systems analysis. Some statements refer to specific risk sources, such as hazardous chemicals (54) and unusual weather (31, 32); to specific waste handling operations (43, 44, 48, 52); or to "what if" questions (33). It is pointed out that LLW disposal has little potential for catastrophe (46), and prescriptions intended to preclude other problems are given (28, A.1.1/103).

2.7.1 Assessment Uncertainties

Assessment uncertainties may be roughly divided into model uncertainties (7, 8, 11, 12, 13) and data or parameter value uncertainties (4, 7, 13). Prominent concerns are model validation, accuracy assessments, and sensitivity analyses to identify important factors. A moderately elaborate systems analysis of SLB (Lester et al. 1981) does contain extensive sensitivity analyses, and underscores the complexity of a site-specific integrated assessment (18-22). It is noted that nonconservative assumptions and estimates have been made (9, 10). A clear example of the completeness problem in fault tree analysis is cited in Raiffa (1980).

2.7.2 Quantification: Risk Measures, Valuation, Comparisons

Several statements incorporate questions as to an appropriate measure for a risk and the value that should be assigned to it in making comparisons (18). Some statements touch on issues that can be sensitive as regards acceptability (1, 7, 8, 12, 17, 20); among these are statements on how public hazards should be stated (6, 9, 15). One common view not always followed is that both individual risks and total population risks should be stated (Kahn 1979). Other concerns are balancing of consequences and probabilities (3, 4, 5, 21) and other trade-offs (2, 8, 11, 14).

2.7.3 Specific Risk Statements

The specific risk statements refer to transportation (1, 13); use of surrogate information (11, 14); sabotage (2, 10, 19); attractive contaminated objects (4); and diverse other specifics, including the relevance of coal-ash disposal experience to FUSRAP (7) and exposure to natural radioactivity (18).

2.7.4 Long-Term Future

The long-term future has precedence in regulatory objectives (A.1.1/76, 101), but the uncertainties of projections of risk on the time scale set by the wastes tend to limit statements to generalities (16-20). Some statements collected here question whether risk assessments can be made (6, 7, 12) and others whether they should be made (1, 2, 3, 11). Two mention assessments 1000 years into the future (9, 10).

It is proposed as a criterion that risks to future generations should not exceed limits presently acceptable (4, 5), and the Natural Resources Defense Council further advocates that these risks should not exceed those that would exist if the original ores had never been mined (Cochran et al. 1979). An NRC statement regarding mill tailings summarizes physical considerations (14).

2.8 WASTE

The character of the waste, in particular, the specific activity of different radionuclides and also the concentrations of any hazardous chemicals that may be present, is a matter of major concern. This is so because the waste characteristics determine the need for containment in a disposal site and the consequences of human exposure that may occur as a consequence of releases from the site. The categories used for classifying statements related to the waste before it is placed in a disposal site are: (1) characterization and classification; (2) packaging; and (3) treatment. The distribution of statements among these subcategories is given in Table 2.8. Most (64%) of the statements were related to characterization and classification; 16% concerned packaging; 9% concerned treatment; and 11% were general waste concerns that did not fit into any one of the three categories.

The largest number of general statements concerned sources and amounts of waste (1-5, 9-11). A general list of waste issues was provided (1), and several statements were comments regarding chemical hazards (6-8).

Table 2.8. Number of Statements and Percent of Total in Each Subcategory Relating to Waste

Category	Statements	
	No.	% of total
Characterization and Classification (A.8.1) ^{†1}	83	72%
Packaging (A.8.2)	21	18%
Treatment (A.8.3)	<u>11</u>	10%
	115	

^{†1} The corresponding subsection of Appendix A is given in parentheses for each category listed.

2.8.1 Characterization and Classification

A considerable number of the statements are concerned with the basis of and suggestions for waste classification (1-14, 17, 20, 21, 25, 26, 29, 31, 36, 39, 40, 51, 52, 81). This reflects the fact that references appeared during a period when the rules for waste classification were under active development. Statements concerning existing and proposed classes of low-level waste are well represented (19, 23, 54, 55, 59-63, 66-68, 73). It should be noted, however, that the current proposed classification scheme for waste that is acceptable at a near-surface burial site for low-level waste excludes waste that presents a danger to public health and safety after 500 years (63, 83). This restriction might exclude most FUSRAP waste. A number of statements concern the issue of classifying the waste according to the "total hazard" (17, 20, 21, 28, 31-33, 37, 53); the NRC response to this concern (classification is by radiation protection considerations, other hazards are addressed by exclusion or treatment) also is given (56, 82). The problem of de minimus standards is raised in several statements (13, 22, 30), and the NRC response that generic de minimus standards will not be given (in 10 CFR 61) but will be determined on a specific waste basis, is stated (57). The point is made that regulations allow releases of gaseous and liquid wastes, but not solid wastes, below a certain concentration (34, 35). Problems of characterizing waste are noted (37, 40, 41, 43, 47), and the need for instrumentation for characterization at the disposal site is noted (24, 45, 46); the only suggestion for resolution of this problem is that waste characterization can best be done at the source (44). The importance of considering chemical hazards is noted (18, 76, 82). (It is implicit in the more numerous statements concerning classification by total hazard.)

2.8.2 Packaging

Several statements are concerned with existing or proposed criteria (7-9, 11, 15, 17), and with the issue of the kind of packaging that can be used, in particular, 55-gallon drums or bulk containers (3, 4). The need to package in a manner that allows efficient placement in the trench is noted (6, 19, 20). The point is made that hazards from current LLW packaging and disposal practices are extremely small (10). Several statements make the point that no credit (for estimating releases) is taken for containment barriers provide by packaging.

2.8.3 Treatment

Most of the statements regarding treatment of low-level waste are not applicable to FUSRAP waste, which is not readily compacted by any appreciable amount. Relevant comments include a question regarding the feasibility of dilution to acceptable activity levels (3, 7), and the comment that it is desirable to minimize the volume of waste generated by remedial actions (6).

2.9 TRANSPORTATION

Issues related to transportation were not considered to be within the scope of this survey, and references devoted to this topic (which are numerous) were excluded from review. The fact that the topic of transportation came up with some frequency in the references selected is an indication of the fact that there is considerable overlap between transportation issues and near-surface disposal site issues per se. The few statements that have been included in this survey concern tradeoffs between transportation and optimum-site-selection factors (1, 2, 5, 10, 11, 17, 19, 20, 23-25), the effect of transportation requirements on packaging (3, 7-9, 12, 18, 26), and various regulatory aspects (4, 15, 16, 21, 22, 27).

2.10 SITE SELECTION

It is intended that appendix material that corresponds to this section (Appendix A.10) provide a compact yet reasonably thorough summary of considerations and strictures important to NSB site selection. All statements found here have already appeared in preceding sections that address the details of the considerations involved, and a complete listing of all pertinent statements has not been attempted.

The general (or miscellaneous) statements deal with site location (2, 15, 20) and availability (3, 12, 13), regional site preference (6, 7, 14), regulations (5, 18-20), site design (1, 8, 9, 11, 16), and disposal alternative evaluation (10).

Under objectives and taxonomy of major considerations (A.10.1) are statements of goals (1, 13, 16), short lists of major selection factors (11, 12, 14, 15, 17), and the LLWMP prescriptive recommendations (2-7).

Under prescriptive guidance (A.10.2) are given the prescriptive requirements of 10 CFR 61. To these could be added rules for mill tailings (A.1.1/75-80)

Preliminary screening (A.10.2) statements were taken from the Description of FUSRAP (USDOE 1980b) and the LLWMP Siting Process (USDOE 1981a). It is possible--indeed probable--that regional-compact states rather than just single states will share in screening. Formation of Northwestern and Southeastern compacts is well advanced, and the Midwest is not far behind.

2.11 OTHER LAND DISPOSAL OPTIONS

In this report, the focus is on near-surface burial, and there is no intent to expand its scope. However, the review produced a number of statements pertaining to other land disposal options that are not excluded, as far as is known by the authors. It is not clear, for example, just which deeper

burial methods also fall under near-surface burial. It seems conceivable that some use of engineered structures, perhaps in combination with stabilization, could be advantageous. Accordingly, it seemed useful to collect some of these statements, without comment, in a separate section (A.11).

3. REFERENCES

- Adam, J.A., and V.L. Rogers. 1978. A Classification System for Radioactive Waste Disposal - What Waste Goes Where? NUREG-0456 (FBDU-224-10). Prepared by Ford, Bacon and Davis, Utah, Inc., Salt Lake City, for the U.S. Nuclear Regulatory Commission, Washington, DC.
- Adam, J.A. 1979. Disposal classification of low-level radioactive waste, pp. 214-218. In J.E. Watson, Jr. (ed.), Low-Level Radioactive Waste Management. Proceedings of Health Physics Society Twelfth Midyear Topical Symposium. EPA 520/3-79-002. Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, DC.
- Blaylock, B.G., and C.S. Fore. 1980. Radioactive wastes. J. Water Pollut. Control Fed. 52(6):1467-1494.
- Blaylock, B.G., and C.S. Fore. 1981. Radioactive wastes: an overview of the 1980 literature. J. Water Pollut. Control Fed. - preprint, April 1981.
- Cluett, C., C. Sawyer, M. Olsen, and D. Manninen. 1979. Social and Economic Aspects of Nuclear Waste Management Activities: Impacts and Analytic Approaches. B-HARC-411-028. Prepared by Battelle Human Affairs Research Centers, Seattle, WA, for the Office of Nuclear Waste Isolation.
- Cochran, T., D. Rotow, and A. Tamplin. 1979. Radioactive Waste Management. Prepared by Natural Resources Defense Council, Inc., Washington, DC., for the U.S. Department of Energy, Washington, DC.
- Cohen, B.L., and H.N. Jow. 1978. A generic hazard evaluation of low-level waste burial grounds. Nucl. Technol. 41:381-388.
- Comptroller General of the United States. 1980. The Problem of Disposing of Nuclear Low-level Waste: Where Do We Go from Here? EMD-80-68. GAO Report to the Congress of the United States: Where Do We Go from Here?
- Council of State Governments. 1981. Summary report and transcript of the central regional workshop on the preliminary draft 10 CFR 61, Chicago, July 17-18, 1980. Available at the U.S. Nuclear Regulatory Commission Public Document Room under Docket No. PR-61.
- Deichman, J.L. (Chairman). 1979. Unresolved Technical Issues in Land Burial of Low-level Radioactive Waste. ORNL/NFW-79/62. U.S. Department of Energy, Washington DC.

- Deichman, J. 1980. Unresolved technical issues for shallow and intermediate depth burial of nuclear waste, pp. 51-63. In R.G. Post (ed.), The State of Waste Disposal Technology, Mill Tailings and Risk Analysis Models, Vol. 1. Proceedings of the Symposium on Waste Management at Tuscon, Arizona, March 10-14.
- DiSibio, R.R. 1980. Low-level waste policy needs from a regional perspective, pp. 3-8. In R.G. Post (ed.), The State of Waste Disposal Technology, Mill Tailings and Risk Analysis Models, Vol. 1. Proceedings of the Symposium on Waste Management at Tuscon, Arizona, March 10-14.
- Doherty, J.F. (Armadillo Coalition of Texas, Houston Chapter). 1978. Public comment on: Advance Notice of Proposed Rulemaking Regarding Management and Disposal of Low-level Wastes by Shallow Land Burial and Alternative Disposal Methods (43 FR 49811, Oct. 25, 1978). Docket No. PR-61 (43 FR 49811). Dec. 21.
- Erb, J.C. 1979. An assessment of the environmental transport of radioiodine in the air-grass-cow-milk pathway using reported environmental monitoring data, pp. 504-513. In J.E. Watson, Jr. (ed.), Low-Level Radioactive Waste Management. Proceedings of Health Physics Society Twelfth Midyear Topical Symposium. EPA 520/3-79-002. Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, DC.
- Falconer, K.L., L.C. Hull, and S.A. Mizell. 1981. Site Selection Criteria for the Shallow Land Burial of Low-level Radioactive Waste. EGG-WM-5393. Prepared by EG&G Idaho, Inc., for the U.S. Department of Energy, Washington, DC.
- Farhar, B.C., C.T. Unseld, R. Vories, and R. Crews. 1980. Public opinion about energy. Ann. Rev. Energy 5:141-72.
- Fore, C.S., N.D. Vaughan, and L.K. Hyder. 1978. Low-level Radioactive Waste Technology: A Selected Annotated Bibliography, Vol. 1. ORNL/EIS-133/V1. Prepared by Oak Ridge National Laboratory, Oak Ridge, TN, for the Office of the Deputy Assistant Secretary for Nuclear Waste Management, U.S. Department of Energy, Washington, DC.
- Fore, C.S., N.D. Vaughan, and L.K. Hyder. 1980. Low-level Radioactive Waste Technology: A Selected Annotated Bibliography, Vol. 2. ORNL/EIS-133/V2. Prepared by Oak Ridge National Laboratory, Oak Ridge, TN, for the Office of the Deputy Assistant Secretary for Nuclear Waste Management, U.S. Department of Energy, Washington, DC.
- Healy, J.W. 1980. Burial limits for radioactive waste, pp. 21-29. In R.G. Post (ed.), The State of Waste Disposal Technology, Mill Tailings, and Risk Analysis Models, Vol. 1. Proceedings of the Symposium on Waste Management at Tucson, Arizona, March 10-14.
- Hebert, J.A. (Coordinator), W.L. Rankin, P.G. Brown, C.R. Schuller, R.F. Smith, J.A. Goodnight, and H.E. Lippek. 1978. Nontechnical Issues in Waste Management: Ethical, Institutional, and Political Concerns. PNL-2400, UC-70. Prepared for the U.S. Department of Energy by the Battelle Human Affairs Research Centers, Seattle, WA.

- Hilpert, L.S. 1969. uranium resources of northwestern New Mexico. Geol. Surv. Prof. Pap. 603. U.S. Government Printing Office, Washington, DC.
- International Atomic Energy Agency. 1981. Shallow Ground Disposal of Radioactive Wastes: A Guidebook. Safety Series No. 53. Vienna, Austria.
- Jacobs, D.G., J.S. Epler, and R.R. Rose. 1980. Identification of Technical Problems Encountered in the Shallow Land Burial of Low-level Radioactive Wastes. ORNL/SUB-80/13619/1. Prepared by Evaluation Research Corporation for Oak Ridge National Laboratory, Oak Ridge, TN.
- Kahn, H. 1979. Interesting aspects of risk calculation, p. 73. In Proceedings of the Symposium/Workshop on Nuclear and Nonnuclear Energy Systems: Risk Assessment and Governmental Decision Making. MTR-79W00335. The MITRE Corporation, McLean, VA.
- Kuck, P.H., and M.E. Wacks. 1980. Alternatives to shallow land burial, pp. 39-49. In R.G. Post (ed.), The State of Waste Disposal Technology, Mill Tailings, and Risk Analysis Models, Vol. 1. Proceedings of the Symposium on Waste Management at Tucson, Arizona, March 10-14.
- Lamb, H.H. 1977. Climate - Present, Past and Future. Vol. 2. Climatic History and the Future. Methuen and Co. Ltd., London; Barnes and Noble Books, New York.
- Lash, T.R. (Natural Resources Defense Council). 1979. Public comment on: Advance Notice of Proposed Rulemaking Regarding Management and Disposal of Low-level Wastes by Shallow Land Burial and Alternative Disposal Methods (43 FR 49811, Oct. 25, 1978). Docket No. PR-61 (43 FR 49811). Jan. 1. 1979.
- Lester, D., et al. 1981. System Analysis of Shallow Land Burial. NUREG/CR-1963. Vol. 1, Code Manual; Vol. 2, Technical Background; Vol. 3, Appendix. Prepared by Science Applications, Inc., LaJolla, CA, for the U.S. Nuclear Regulatory Commission, Washington, DC.
- Levin, G.B. (Chairman). 1980. Managing Low-level Radioactive Waste -- A Proposed Approach. LLWMP-1. Prepared by EG&G Idaho, Inc., for the U.S. Department of Energy Washington, DC.
- Lipton, W.V., N.W. Golchert, and J. Sedlet. 1981. Current State of Knowledge: Environmental Monitoring of Low-level Radioactive Waste Disposal Sites. Low-level Waste Technology working paper. Argonne National Laboratory, Argonne, IL.
- Macbeth, P.J., D.E. Christensen, B.J. Thamer, and G. Wehmann. 1978. Screening of Alternative Methods for the Disposal of Low-level Radioactive Waste. NUREG/CR-0308. Prepared by Ford, Bacon and Davis Utah, Inc., Salt Lake City, for the Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC.

- Macbeth, P., G. Wehmann, B. Thamer, and D. Card. 1979. Evaluation of Alternative Methods for the Disposal of Low-level Radioactive Wastes. NUREG/CR-0680. Prepared by Ford, Bacon and Davis Utah, Inc., Salt Lake City, for the Low-Level Waste Branch, U.S. Nuclear Regulatory Commission, Washington, DC.
- Martin, J.E., et al. 1979. Proposed Federal Radiation Guidance for Radioactive Wastes, pp. 284-292. In J.E. Watson, Jr. (ed.), Proceedings of Health Physics Society Twelfth Midyear Topical Symposium. EPA 520/3-79-002. Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, DC.
- Maxey, M.N. 1979. Managing low-level radioactive wastes: bioethical concerns, pp. 400-419. In J.E. Watson, Jr. (ed.), Low-Level Radioactive Waste Management. Proceedings of Health Physics Society Twelfth Midyear Topical Symposium. EPA 520/3-79-002. Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, DC.
- Momeni, M.H., W.E. Kisielewski, S. Tyler, A. Zielen, Y.C. Yuan, and C.J. Roberts. 1979. Radiological Impact of Uranium Tailings and Alternatives for Their Management. Presented at the Health Physics Society Twelfth Midyear Topical Symposium on Low Level Radioactive Waste Management, Feb. 11, 1979.
- Murphy, E.S., and G.M. Holter. 1980. Technology, Safety, and Costs of Decommissioning a Reference Low-level Waste Burial Ground. NUREG/CR-0570. Prepared by Battelle-Pacific Northwest Laboratory, Richland, WA, for the Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, DC.
- National Academy of Sciences. 1979. Energy in Transition, 1985-2010. Final Report of the Committee on Nuclear and Alternative Energy Systems. National Research Council. W.H. Freeman and Company, San Francisco.
- Nelkin, D., and M. Pollack. 1980. Problems and procedures in the regulation of technological risk, pp. 233-254. In R.C. Schwing and W.A. Albers, Jr. (eds.), Societal Risk Assessment: How Safe is Safe Enough? Plenum Press, New York-London.
- New England Regional Commission. 1981. Summary report and transcript of the northeast regional workshop on the preliminary draft 10 CFR 61, November 6-7, 1980. Available at the U.S. Nuclear Regulatory Commission Public Document Room under Docket No. PR-61.
- Oztunali, O.I. 1980. Considerations in regulation of low-level radioactive waste management and disposal, pp. 31-38. In R.G. Post (ed.), The State of Waste Disposal Technology, Mill Tailings, and Risk Analysis Models, Vol. 1. Proceedings of the Symposium on Waste Management at Tucson, Arizona, March 10-14.
- Raiffa, H. 1980. Concluding remarks, pp. 339-342. In R.C. Schwing and W.A. Albers, Jr. (eds.), Societal Risk Assessment: How Safe is Safe Enough? Plenum Press, New York-London.

- Roessler, C.E., et al. 1979. Management of low-level natural radioactivity wastes of phosphate mining and processing, pp. 182-195. In J.E. Watson, Jr. (ed.), Low-Level Radioactive Waste Management. Proceedings of Health Physics Society Twelfth Midyear Topical Symposium. EPA 520/3-79-002. Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, DC.
- Rotow, D., T. Cochran, and A. Tamplin. 1979. NRDC Comments on Criteria for Radioactive Waste Proposed by Environmental Protection Agency, Federal Register, Vol. 43, No. 221, November 15, 1978. Natural Resource Defense Council, Inc., Washington, DC.
- Schilling, A.H., and B. Keen. 1980. An Annotated Bibliography of Topical Reports Related to Radioactive Waste Management. BHARC-301/81/001. Battelle Human Affairs Research Centers, Seattle, WA.
- Shapiro, F.C. 1981. Nuclear waste. The New Yorker, Oct. 19, 1981, pp. 53-139.
- Slovic, P., B. Fischhoff, and S. Lichtenstein. 1980. Facts and fears: understanding perceived risk, pp. 181-216. In R.C. Schwing and W.A. Albers, Jr. (eds.), Societal risk Assessment: How Safe is Safe Enough? Plenum Press, New York-London.
- Southern States Energy Board. 1980. Summary report and transcript of southeast regional workshop on the preliminary draft 10 CFR 61, Atlanta, April 21-22, 1980. Available at the U.S. Nuclear Regulatory Commission Public Document Room under Docket No. PR-61.
- U.S. Department of Energy. 1979. Report to the President by the Interagency Review Group on Nuclear Waste Management. TID-29442.
- U.S. Department of Energy. 1980a. Radioactive Waste Processing and Disposal. NUREG-0643, TID-3311-S8. Prepared by the Technical Information Center for the U.S. Nuclear Regulatory Commission.
- U.S. Department of Energy. 1980b. Description of the Formerly Used Sites Remedial Action Program. DOE/ORO-777. Oak Ridge Operations, Oak Ridge, TN.
- U.S. Department of Energy. 1980c. Understanding Low-level Radioactive Waste. LLWMP-2. Prepared by EG&G Idaho, Inc., for the National Low-level Waste Management Program.
- U.S. Department of Energy. 1981a. The Siting Process: Establishing a Low-level Waste Disposal Facility. LLWMP-6. Prepared by EG&G Idaho, Inc., for the National Low-level Waste Management Program.
- U.S. Department of Energy. 1981b. Managing Low-level Radioactive Wastes - A Technical Analysis. LLWMP-7. Prepared by EG&G Idaho, Inc., for the National Low-level Waste Management Program.

- U.S. Department of Energy. 1981c. Compliance with the National Environmental Policy Act; intent to prepare an environmental impact statement and conduct public scoping meetings for remedial actions at the inactive uranium mill tailings site and vicinity properties in and near Durango, Colorado. Fed. Regist. 46(109):30383-30385.
- U.S. Department of Energy. 1981d. Energy and Environmental Quality: Case Histories of Impact Management. DOE/EP/10012-1. Prepared by Urban Systems Research & Engineering, Inc., Cambridge, Mass., for the Office of Environmental Assessments, Regional Impacts Division, Washington, DC.
- U.S. Environmental Protection Agency. 1977a. Proceedings of a Workshop on Policy and Technical Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes, Vol. 1. Albuquerque, NM, April 12. ORP/CSD-77-1. Office of Radiation Programs.
- U.S. Environmental Protection Agency. 1977b. Policy and technical considerations for intermediate-level and low-level radioactive wastes. In Proceedings of a Workshop on Policy and Technical Issues Pertinent to the Development of Environmental Protection Criteria for Radioactive Wastes, Vol. 2, Albuquerque, NM, April 12, 1977. ORP/CSD-77-2. Office of Radiation Programs.
- U.S. Environmental Protection Agency. 1978. Proceedings of a Public Forum on Environmental Protection Criteria for Radioactive Wastes, Vol. 2, Denver, Colorado, March 28-April 1. ORP/CSD-78-2. Office of Radiation Programs.
- U.S. Environmental Protection Agency. 1980a. Proposed cleanup standards for inactive uranium processing sites. Fed. Regist. 45(79):27370-27375.
- U.S. Environmental Protection Agency. 1980b. 40 CFR 116: Designation of hazardous substances, proposed amendment. Fed. Regist. 45(133):46094-46097.
- U.S. Environmental Protection Agency. 1980c. Standards applicable to owners and operators of hazardous waste treatment, storage and disposal facilities. Fed. Regist. 45(197):66816-66823.
- U.S. Environmental Protection Agency. 1980d. Draft Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites (40 CFR 192). EPA 520/4-80-011. Office of Radiation Programs, Washington, DC.
- U.S. Environmental Protection Agency. 1981a. 40 CFR 192: Proposed disposal standards for inactive uranium processing sites; invitation for comment. Fed. Regist. 46(6):2556-2563.
- U.S. Environmental Protection Agency. 1981b. 40 CFR Parts 122, 264 and 265: Standards applicable to owners and operators of hazardous waste treatment, storage and disposal facilities: consolidated permit regulations. Fed. Regist. 46(7):2802-2897.
- U.S. Environmental Protection Agency. 1981c. Federal radiation protection guidance for occupational exposures; proposed recommendations, request for written comments, and public hearings. Fed. Regist. 46(15):7836-7844.

- U.S. Environmental Protection Agency. 1981d. 40 CFR Parts 122 and 267: Interim standards for owners and operators of new hazardous waste and disposal facilities and EPA administered permit programs: the hazardous waste permit program. Fed. Regist. 46(30):12414-12433.
- U.S. Environmental Protection Agency. 1981e. 40 CFR Part 264: Standards applicable to owners and operators of hazardous waste treatment, storage and disposal facilities - supplemental notice of proposed rulemaking. Fed. Regist. 46(100):28314-28328.
- U.S. Nuclear Regulatory Commission. 1980a. Final Generic Environmental Impact Statement on Uranium Milling. NUREG-0706. Vol. 1, Summary and Text; Vol. 2, Appendices A-F; Vol. 3, Appendices G-V. Office of Nuclear Material Safety and Safeguards, Washington, DC.
- U.S. Nuclear Regulatory Commission. 1980b. 10 CFR 40, Appendix A: Criteria relating to the operation of uranium mills and the disposition of tailings or wastes produced by the extraction or concentration of source material from ores processed primarily for their source material content. Fed. Regist. 45:65521-65538.
- U.S. Nuclear Regulatory Commission. 1981a. 10 CFR Parts 2, 9, 20, 21, 30, 40, 51, 61, 70, 73, and 170. Licensing requirements for land disposal of radioactive waste. Fed. Regist. 46(142):38081-38105.
- U.S. Nuclear Regulatory Commission. 1981b. Draft Environmental Impact Statement on 10 CFR Part 61 "Licensing Requirements for Land Disposal of Radioactive Waste." NUREG-0782. Vol. 1, Summary; Vol. 2, Main Report; Vol. 3, Appendices A-F; Vol. 4, Appendices G-Q. Office of Nuclear Material Safety and Safeguards, Washington, DC.
- U.S. Nuclear Regulatory Commission. 1981c. Data Base for Radioactive Waste Management: Vol. 1 (J.J. Clancy, D.F. Gray, and O.I. Oztunali). Review of Low-Level Radioactive Waste Disposal History. Vol. 2 (R.E. Wild, et al.). Waste Source Options Report. Vol. 3 (O.I. Oztunali et al.). Impacts Analyses Methodology Report. Prepared by Dames and Moore, Inc., White Plains, NY, for Office of Nuclear Material Safety and Safeguards, Washington, DC.
- U.S. Nuclear Regulatory Commission. 1981d. Disposal or onsite storage of thorium or uranium wastes from past operations. Fed. Regist. 46(205):52061-52063.
- Valore, C., Jr., and J.R. Lamarsh (Township of Lower Alloways Creek, Salem County, New Jersey). 1978. Public comment on: Advance Notice of Proposed Rulemaking Regarding Management and Disposal of Low-Level Wastes by Shallow Land Burial and Alternative Disposal Methods (43 FR 49811, Oct. 25, 1978). Docket No. PR-61 (43 FR 49811). Dec. 20, 1978.
- The Waste Paper. 1981a. The Trenchant Report; Remedy for Canonsburg. Vol. 3, No. 3, Summer. Sierra Club Atlantic Chapter Radioactive Waste Campaign, Buffalo, NY. p. 4.

The Waste Paper. 1981b. A Pod of Pods; The \$7 Million Mishap. Vol. 3, No. 4, Fall. Sierra Club Atlantic Chapter Radioactive Waste Campaign, Buffalo, NY. p. 7.

Wenslawski, F.A., and H.S. Worth, Jr. 1979. Response to a widespread, unauthorized dispersal of radioactive waste in the public domain, pp. 492-496. In J.E. Watson, Jr. (ed.), Low-Level Radioactive Waste Management. Proceedings of Health Physics Society Twelfth Midyear Topical Symposium. EPA 520/3-79-002. Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, DC.

Western Interstate Energy Board. 1981. Summary report and transcript of the western regional workshop on the preliminary draft 10 CFR 61, Chicago, July 17-18, 1980. Available at the U.S. Nuclear Regulatory Commission Public Document Room under Docket No. PR-61.

Wilson, J. (Chairman, Stark County, Illinois, Planning Commission). 1978. Public comment on: Advance Notice of Proposed Rulemaking Regarding Management and Disposal of Low-Level Wastes by Shallow Land Burial and Alternative Disposal Methods (43 FR 49811, Oct. 25, 1978). Docket No. PR-61 (43 FR 49811). Dec. 19, 1978.

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A.1.1 Federal Laws and Rulemaking

A.1 INSTITUTIONAL		USEPA (1981a)
A.1.1 Federal Laws and Rulemaking		
1	What is meant by "weight of geological evidence," and "reasonable probability of being affected by movement along a fault," in defining an active fault zone?	USEPA (1981a)
2	Should facilities for hazardous waste disposal be allowed within active fault zones even if designed to withstand seismic activity?	USEPA (1981a)
3	In waste disposal siting standards, should (1) facilities be prohibited within floodplains or (2) facilities be allowed within floodplains if the facility is "properly built?"	USEPA (1981a)
4	Should "Flood of Concern" assessment depend on the degree of hazard imposed by (1) type of hazardous waste buried, and (2) quantity of disposed hazardous waste?	USEPA (1981a)
5	There is concern that floodplain standards would force closure of existing waste disposal facilities.	USEPA (1981a)
6	Should the basis of environmental radiation protection rulemaking be established generically to address all forms and types of radioactive wastes?	USEPA (1981a)
7	For what kind of radioactive waste or disposal conditions might generic rulemaking not apply?	USEPA (1981a)
8	To what extent should the "contain and isolate until decay to innocuous levels" philosophy of disposal apply to rulemaking?	USEPA (1981a)
9	How should rulemaking consider "legacy" and the possible effects of institutional instability on legacy?	USEPA (1981a)
10	What are the trade offs between waste-disposal impacts on present and future generations, and from rules promulgated in the present? Are impacts on present and future generations most important in rule development?	USEPA (1981a)
11	Should the procedure for rulemaking consider cost effectiveness analysis or risk/benefit evaluations? Should a dollar value be established for health-effect mitigation?	USEPA (1981a)
12	Should the procedure for rulemaking consider both "normal" and "accident" impact factors?	USEPA (1981a)
13	Should long-term care (control and surveillance) be included in rulemaking, or is it necessary?	USEPA (1981a)
14	Should rulemaking include preplanned remedial action (in case of accident) requirements, or due to institutional instability, should remedial-action considerations be avoided?	USEPA (1981a)
15	Should abnormal or unplanned impacts be considered in the waste-disposal rulemaking procedure?	USEPA (1981a)
16	Should rulemaking uniformly mitigate risks caused by disposal of all radioactive wastes?	USEPA (1977b)
17	Should existing disposal sites be addressed in rulemaking in order to protect both present and future generations?	USEPA (1977b)
18	Should the proposed rulemaking address the present and future use of waste materials?	USEPA (1977b)
19	Should remedial measures be preplanned to contend with accidents at a deactivated/decommissioned low-level waste site, or, because of the nature of the waste and uncertainty of institutional stability in the future, should this approach be avoided?	USEPA (1977b)
20	Considerations of risks to future generations should be included in the bases for low-level waste disposal rulemaking.	USEPA (1977b)
21	Development of data bases is more important to the formulation of standards than for the development of regulatory criteria.	USEPA (1977b)
22	The approach to rulemaking should require that maximum individual and population (radiation) doses be taken into account in standards setting.	USEPA (1977b)
23	How do rulemaking considerations specifically address the definition of past, present, and future radioactive wastes?	USEPA (1978)

- 24 Should (rule-making considerations) address human contamination such as excreta and body burdens of radioactive materials? USEPA (1978)
- 25 Do current regulations (rules) provide assurance that radioactive materials that are restricted from routine release to the biosphere will be properly classified as waste? USEPA (1978)
- 26 What methods should be used to derive a minimum (acceptable radiation) level? USEPA (1978)
- 27 Should regulatory considerations attempt to address the designation of no resource or product value, and who should make that decision? USEPA (1978)
- 28 (As of July 9, 1980) New carcinogenic regulations are unnecessary, because carcinogens are currently regulated under other statutes. USEPA (1980b)
- 29 Cleanup standards should be unambiguous. It should be clear whether or not a situation meets the standard. USEPA (1980a)
- 30 Cleanup standards should be cost-related. The cost should be related to the amount of injury prevented. USEPA (1980a)
- 31 Cleanup standards should be practical. They must accomplish the (disposal) requirements in a reasonable time with the techniques and personnel available. USEPA (1980a)
- 32 Are there situations that may require exposure to doses higher than normally permitted and, in these cases, should special guidance be provided. USEPA (1981c)
- 33 What radiation guidance should apply to workers who do not use (are not otherwise exposed to) radiation sources, but who are exposed to radiation due to the activities of workers under the control of other employers? USEPA (1981c)
- 34 What relationship should be maintained between permissible levels of risk to health from radiation exposure and other regulated hazards of disease or accidents? USEPA (1981c)
- 35 How should the radiation protection principles requiring (a) justification of any exposure, and (b) reduction of the dose from justified exposure to the lowest practicable or as low as is reasonably achievable level be applied to exposure of workers? Should the concept of lowest feasible level be applied to exposure of workers? USEPA (1981c)
- 36 Should the radiation guidance reflect or cover medical, accidental, and/or emergency exposures? USEPA (1981c)
- 37 Should the same radiation guides apply to all categories of workers? USEPA (1981c)
- 38 BY 1981, DOE and NRC should review existing and alternative LLW disposal techniques and determine whether any should be adopted in the near future. USD OE (1979)
- 39 Need exists for the establishment of perpetual care standards for new methods of waste disposal. USD OE (1979)
- 40 Waste management requirements should not be proposed beyond those already required by federal and state agencies because the half life of these wastes is very short and isolation for long periods of time is unnecessary. USD OE (1979)
- 41 Adequate definition of LLW is lacking, and needed for optimal screening of disposal options (e.g. SLB, Intermediate Depth Land Burial (IDLB), landfill). Compt. Gen. of U. S. (1980)
- 42 Should any new SIB sites be licensed before DOE has developed a national LLW plan? Compt. Gen. of U. S. (1980)
- 43 Regulations and incentives should be combined to encourage optimal LLW treatment techniques. Levin (1980)
- 44 Acceptable levels should be established for safe release of solids as well as liquids and gases into the environment. Levin (1980)
- 45 Interim storage onsite or offsite should be allowed while disposal capacity is being developed. Levin (1980)
- 46 Unrestricted (post-closure) use is unrealistic, and restricted use acceptability needs be addressed. Macbeth et al. (1978)
- 47 Decommissioning is unlikely and would depend on how much D&D is needed. Includes its consideration to assure the public that all aspects have been examined. Macbeth et al. (1978)
- 48 Public hazards should be analyzed in terms of integrated long-term dose commitment. Macbeth et al. (1978)
- 49 Public hazard should be ALARA. Macbeth et al. (1978)
- 50 Is disposal in manmade structures an acceptable and cost-effective alternative for some FUSRAP waste? Macbeth et al. (1978)
- 51 NRC should provide for an expanded role for non agreement states in the licensing process, and should provide more definite guidelines to agreement states for minimum regulatory requirements. USD OE (1980c)
- 52 New DOE LLW non-defense sites would also be licensed. USD OE (1980c)
- 53 NRC regulatory program and DOE technical assistance and development programs (must conform to) EPA standards, but these are not scheduled to be published until 1984. USD OE (1980c)
- 54 Acceptable levels should be established for the safe release of solids as well as liquids and gases into the environment. USD OE (1980c)
- 55 LLW transportation is regulated by DOT (packaging and handling, vehicle safety and maintenance), USCG (transport over water), BOD, DOE (shipment in noncivilian vehicles, aircraft, ships), and NRC (responsible for developing performance standards for large shipments). USD OE (1980c)

- 56 DOE could promulgate re-educational standards for each site at which it is necessary to begin remedial action before the [EPA] administrator promulgates standards of general application. USD OE (1980b)
- 57 Legislative authority must be established by which the federal government (DOE) can act to correct problems of radioactive contamination at formerly used sites. USD OE (1980b)
- 58 It is assumed for FUSRAP that (1) DOE will own and maintain all stabilized, interim, and permanent disposal sites except where affected states agree to accept ownership and custodial responsibilities. (2) All stabilized, interim, and permanent disposal sites will be licensed by NRC. USD OE (1980b)
- 59 Selection of the disposal site will take into consideration, as appropriate, preliminary NRC licensing evaluation of the site. USD OE (1980b)
- 60 Licensing authority of NRC does not include naturally occurring or accelerator produced radioactive materials, which are under jurisdiction of the states. Lipton (1981)
- 61 Site selection shall be consistent with federal, state, and local laws and regulations. Federal laws include: Clean Air Act, Clean Water Act, Safe Drinking Water Act, NEPA. Falconer et al. (1981)
- 62 The site shall not be within areas protected from such use by federal, state, or local laws and regulations. Federal laws include: Wilderness Act of 1964, Wild and Scenic Rivers Act of 1968, National Wildlife Refuge Act of 1966, National Parks National Historical Preservation Act of 1966, Archaeological and Historical Preservation Act of 1974, Heritage Conservation and Recreation Service. Falconer et al. (1981)
- 63 Preliminary information from [NRC] indicates that licensing a site takes at least two years. Estimates for the time required for the siting process, including site development could range from three to five years. USD OE (1981a)
- 64 Technical and economic factors affecting licensing and site design include requirements for: design, pre-operational monitoring, waste acceptance, operations and environmental modeling, closure, operational and extended care funding. USD OE (1981a)
- 65 The site applicant prepares a program to explain the planned siting approach and the schedule for developing and operating the site, which incorporates or identifies additional documents to be prepared: preliminary criteria for waste acceptance and facility design, final criteria for detailed site characterization and selection, state agencies responsible for selecting a site contractor or operating the site. USD OE (1981a)
- 66 The facility operating license in a nonagreement state must be renewed at least every five years. States may have similar renewal requirements. USD OE (1981a)

- 67 The issue of environmental releases deserves a high priority. Central is the lack of consistency between current requirements for disposal of LLW in solid form and regulations allowing certain concentrations of liquid and gaseous radioactive materials to be released to the environment. USD OE (1981b)
- 68 The principle of dilution and dispersion has long been an accepted treatment for certain pollutants, and is the basis of current practice [when] releases of radioactive liquids and gases [is allowed]. USD OE (1981b)
- 69 Current practice does not allow the release of solid radioactive waste into the environment. Items with surface activity can be decontaminated and recycled, but items with internal contamination from neutron activation must be shipped to disposal sites whatever their potential of hazard. USD OE (1981b)
- 70 Frequent reports of discovery of abandoned, illegal dumps of hazardous chemical wastes and the fact that operational problems contributed to closing the Haxey Flats and West Valley sites have led to widespread demands that the regulatory framework be "tight" enough to ensure that high standards for safe disposal will be maintained. USD OE (1981b)
- 71 Most improvements in SLB [of significance which] have been suggested [as solutions to problems encountered] have been included in NRC proposed regulations (10 CFR 61). USD OE (1981b)
- 72 The major deficiency [of 10 CFR 61] is a paucity of information regarding the handling of chemical hazards. USD OE (1981b)
- 73 The regulatory framework requisite for disposal according to the nature of the waste will not be fully established for several years. USD OE (1981b)
- 74 Maintaining institutional controls for longer periods (essentially in perpetuity because of the long half-lives involved) does not seem feasible. Adam and Rogers (1978)
- 75 Both public acceptance and existing regulatory controls appear to be adequate for continuing present SLB practice. Macbeth et al. (1979)
- 76 The specifications shall be developed considering the expected full capacity of tailings or waste systems. USNRC (1980b)
- 77 Primary emphasis shall be given to long term isolation of tailings or waste as opposed to short term convenience or benefits such as minimization of transportation or land acquisition costs. USNRC (1980b)
- 78 The "prime option" for tailings disposal is placement below grade either in mines or specially excavated sites (that is, where there is no need for any specially constructed retention structure). USNRC (1980b)
- 79 While the primary method of protecting groundwater shall be isolation of tailings, disposal involving contact with groundwater will be considered provided it is demonstrated that the groundwater will not be degraded from current or potential uses. USNRC (1980b)

80 USHRC (1980b)
Ownership of certain severable subsurface interests (for example, mineral rights) may be determined to be unnecessary to protect the public health and safety and the environment.

81 USHRC (1980b)
The final disposition of tailings or wastes at milling sites should be such that ongoing maintenances is not necessary to preserve isolation.

82 Healy (1980)
The EPA procedure for setting dose limits, applied to the setting of general standards, reduces the flexibility that can be applied by the using Agency and provides standards in which the outcome cannot be predicted before the standard is available. Thus, we find ourselves in the position of having no general guidance for the Agencies to follow so that they must wait until the more specific standard covering a proposed action is issued before they can take action or run risk of having action taken on the wrong basis. This has led to situations where individuals propose interim guidance at as low a level as they can conceive of (and often, perhaps, below a level at which the job can be done). The public believes that a standard of this nature represents a precipice between life and death. Thus, when the standards are exceeded, the public believes that they have been exposed to a dangerous situation and react accordingly.

83 Healy (1980)
Limits for wastes disposed of in long-lasting containers should be lower, to control intruder doses, than for limits in which degradation and mixing with the soil can be expected. Note that the present regulatory trend of requiring containers as long-term barriers will accentuate the problem.

84 Deichman (1980)
A potential radiological hazard from buried waste persists for a considerable period beyond the time when wastes are replaced. Unrestricted decommissioning of the site will not be permissible until it can be shown that further control and surveillance are no longer required.

85 USEPA (1980d)
Standards require cleanup of open land contaminated by tailings when the average radium concentration attributable to tailings exceeds 5 pCi/gm. This is three to five times the average radium concentration in normal U.S. soil.

86 USEPA (1980d)
EPA proposes to require a reasonable expectation that the radon emission and water protection standards for tailings disposal will be satisfied for at least one thousand years. Pragmatism suggests the choice of a thousand-year period, though technically and economically reasonable disposal methods may, for some tailings piles, afford even longer protection.

87 USEPA (1980d)
For any open land contaminated with tailings, the average radium concentration in any five-centimeter-thick layer within one foot of the surface, or any 15 cm layer below one foot, shall not be more than 5 pCi/gm after cleanup.

88 USEPA (1980d)
The proposed action level for gamma radiation, 0.02 mR/hr above background, allows some limited flexibility in the methods chosen to reduce indoor radon decay product concentrations.

89 USHRC (1981a)
In general, the 10CFR61 proposed rules set forth performance objectives, with such prescriptive requirements as have been judged necessary in the light of past disposal site operating experience, such requirements being stated as minimum criteria as far as is practicable.

90 USHRC (1981a)
NRC is applying a 500 mrem/yr maximum individual exposure limit for the unusual case of inadvertent intrusion (which may never occur), based on ICRP recommendations.

91 USHRC (1981a)
NRC does not anticipate that EPA standard for release of radioactivity to the environment from disposal facilities, when promulgated, will be much higher than that for release to the environment from fuel cycle facilities (25 mrem/yr whole body exposure; 40CFR190) or any lower than that for radioactivity in drinking water (4 mrem/yr whole-body exposure, 40CFR141).

92 USHRC (1981a)
NRC has not developed a classification of waste, based on the total hazard. The classification is based on radiation protection considerations. Other hazards presented by associated components of waste (e.g., chemical and biological hazards) are addressed by exclusion or treatment of certain chemical, physical, and biological forms of waste.

93 USHRC (1981a)
NRC recognizes the need for a "de minimis" classification of wastes, wastes which would be exempt from Part 61 and of no regulatory concern. Such exceptions should, however, be determined on a specific waste basis (as for tritium and C-14) and Part 61 will not establish a generic "de minimis" category for waste.

94 USHRC (1981a)
Reliance on active institutional controls for more than 100 years will not be allowed, since this is judged to be the maximum time that governmental institutions can be relied upon to carry out active controls.

95 USHRC (1981a)
It would be the Commission's intent that in the future all disposal would be expected to comply with the provisions of Part 61.

96 USHRC (1981a)
Although the Commission has no direct statutory authority over naturally occurring and accelerator-produced radionuclides the evaluation of any specific disposal site will include consideration of the total impacts from all waste disposed of at the site, including byproduct, source, and special nuclear material, and naturally occurring and accelerator-produced material.

97 USHRC (1981a)
For the purpose of this chapter, a geologic repository as defined in Part 60 is not considered a land disposal facility.

98 USHRC (1981a)
Near-surface disposal facility means land disposal facility in which radioactive waste is disposed of in or within the upper 15-20 meters of the earth's surface.

99 USHRC (1981a)
Migration analysis [in license applications] must identify and differentiate between roles of natural site characteristics and design features in isolating and segregating the wastes.

100 USHRC (1981a)
Analysis in license applications must provide reasonable assurance that performance objectives will be met.

- 101 USNRC (1981a)
[Closure applications must include] any significant new information on the environmental impact of closure activities and on long-term performance of the site.
- 102 USNRC (1981a)
Primary emphasis in site suitability is on isolation of the waste, and on disposal site features that assure that the long-term performance objectives are met, as opposed to short term convenience or benefits.
- 103 USNRC (1981a)
The disposal site shall be capable of being characterized, modeled, analyzed, and monitored.
- 104 USNRC (1981a)
A disposal site should be selected so that projected population growth and future developments are not likely to affect the ability of the site to meet the performance objectives.
- 105 USNRC (1981a)
Disposal site suitability requirements for land disposal other than near-surface [are for future rulemaking].
- 106 USNRC (1981a)
Site design must be directed toward long-term isolation and avoidance of active maintenance.
- 107 USNRC (1981a)
Site design and operation must be compatible with [an adequate] site closure and stabilization plan.
- 108 USNRC (1981a)
Site design must complement and improve the site's natural characteristics in re performance objectives.
- 109 USNRC (1981a)
The disposal site shall be used exclusively for the disposal of radioactive wastes.
- 110 USNRC (1981a)
Disposal site design [requirements] for other than near-surface disposal [are reserved for future rulemaking].
- 111 USNRC (1981a)
Facility operations and disposal site closure [requirements] for land disposal facilities other than near-surface [are reserved for future rulemaking].
- 112 USNRC (1981a)
NRC may, upon request or on its own initiative, authorize provisions other than those set forth in sections 61.51 through 61.53 for the segregation and disposal of waste and for the design and operation of a land disposal facility on a specific basis, if it finds reasonable assurance of compliance with the performance objectives of Subpart C of this part.
- 113 USNRC (1981a)
Waste [whose] radioisotope concentration exceeds the values shown in Column 3 Table I, of this section is not generally acceptable for near-surface disposal.
- 114 USNRC (1981a)
Minimum requirements for all classes of waste which is to be disposed of by near-surface burial include: (1) waste must be packaged and the waste form and packaging must meet all applicable transportation requirements of NRC (10 CFR 71) and DOT (49 CFR 171-179); (2) wastes must not be packaged for disposal in cardboard or fiberboard boxes.
- 115 USNRC (1981a)
10 CFR 61.56(a) (4)-(8) lists several minimum requirements for all classes of waste which pertain to non-radiological hazards that are unlikely to be significant in the FUSRAP wastes themselves. Requirement (3) pertains to liquids in wastes. These requirements may apply to wastes generated by remedial actions.

- 116 USNRC (1981a)
Stability requirements are intended to assure for at least 150 years that the waste does not degrade and promote disposal unit failure leading to water infiltration.
- 117 USNRC (1981a)
NRC may, upon request or on its own initiative, authorize other provisions for the classification of waste on a specific basis, if, after evaluation of the specific characteristics of the waste, the disposal site, and method of disposal, it finds reasonable assurance of compliance with the performance objectives.
- 118 USNRC (1981a)
An applicant for license must provide, prior to commencement of operations, assurance that sufficient funds will be available for the disposal site closure and stabilization, including decontamination or dismantling facility structures, and such operations or activities as are needed to ensure that no active maintenance will be needed during the postclosure period.
- 119 Murphy and Holter (1980)
Although agreement states can presumably adopt regulations applicable to decommissioning of LLH burial grounds, none appear to have done so. Nor is decommissioning explicitly treated in current license agreements.
- 120 Murphy and Holter (1980)
Little information is currently available on the hazardous chemical content of LLH waste trenches. The migration of hazardous chemicals is a very serious concern, and an environmental analysis of the impact of hazardous chemical migration from LLH burial trenches should be undertaken in the future.

A.1.2 State, Local, and Federal Conflicts; Regional Issues

- 1 USDOE (1979)
Joint federal/state planning activities in radwaste management should be identified.
- 2 USDOE (1979)
Appropriate existing or new mechanisms and timetable should be identified and agreed upon for carrying on joint federal/state planning activities for radwaste management.
- 3 USDOE (1979)
Constructive state participation in radwaste management programs requires individual states to establish organizations which should be funded by the federal government.
- 4 USDOE (1979)
Develop regional waste disposal siting plans and support state "consultation and concurrence" activities.
- 5 USDOE (1979)
There is concern whether any state will accept location of a federally proposed waste-disposal site within that state.
- 6 Levin (1980)
Federal/state regulatory authority should be via a modified agreement state program, for flexibility and federal funding.
- 7 Levin (1980)
DOE should initiate a study to clarify liabilities in all waste management sectors.

- 8 States should have the option of enforcing federal transportation regulations. Levin (1980)
- 9 Transportation routing rules should be set by the federal government with state participation. Levin (1980)
- 10 States should design their own emergency response systems with federal guidance and assistance. Levin (1980)
- 11 Federal/state disposal responsibility should be divided according to isolation required for waste. Levin (1980)
- 12 Disposal site owner should lease facility to private industry to operate. Levin (1980)
- 13 States should have option to transfer disposal sites to federal government for extended care monitoring after closure. Levin (1980)
- 14 DOE should continue to regulate its sites, with monitoring by states allowed. Levin (1980)
- 15 Compatibility with other programs should be taken into account. Macbeth et al. (1978)
- 16 The IRG recommends that states be provided the option to retain management control of existing commercial LLW sites or to transfer control to the federal government. USDQE (1980c)
- 17 NRC should provide for an expanded role for non agreement states in the licensing process, and should provide more definite guidelines to agreement states for minimum regulatory requirements. USDQE (1980c)
- 18 Is there significant chance of adverse impact on on FUSRAP disposal arising from potential for state authority to exclude out-of-state or out-of-region wastes? USDQE (1980c)
- 19 State Planning Council recommends that host states or regional compacts should be authorized by federal statute to exclude from their disposal sites waste generated outside the state or region. USDQE (1980c)
- 20 The SPC urges EPA to complete a position paper on LLW radiation protection for use by the federal agencies [NRC and DOE] until final standards are promulgated. USDQE (1980c)
- 21 National Conference of State Legislatures [believes] that the primary responsibility for management of low-level radioactive waste rests with the states. USDQE (1980c)
- 22 In October 1979, temporary closure of two of the nation's three commercial LLW disposal sites was precipitated by the consistent failure of several state and federal agencies to adequately enforce waste packaging and transportation regulations.[NSA]

- 23 [A] regional[compact]approach is preferable to federal preemption or 50 separate sites, based on considerations of cost, transportation, political issues, and health and safety factors.[NSA] USDQE (1980c)
- 24 Congress should pass legislation authorizing states to enter into interstate compacts to establish regional disposal sites. Such authorization is necessary to exclude waste generated outside the region from the regional disposal site.[NSA] USDQE (1980c)
- 25 NRC must develop a simple LLW classification system based on total hazard which includes upper and lower concentration bounds. USDQE (1980c)
- 26 [New] legislative authority will be required to clarify DOE's authority for remedial action at 18 of the FUSRAP sites and for acquisition and disposition of disposal sites---DOE has proposed legislation to provide such authority. What, if any, impact on FUSRAP timetables is implied? USDQE (1980b)
- 27 States in which radioactive contaminated sites are located would be responsible for locating suitable disposal sites for the residual radioactive material. USDQE (1980b)
- 28 The state is to identify candidate disposal sites for subsequent study during the [preliminary] engineering and environmental evaluation. DOE would support screening studies. USDQE (1980b)
- 29 Results of preliminary engineering evaluation, environmental analysis, and DOE conclusions as to preferred waste disposal option and reasonable alternatives will be communicated, for review and comment, by DOE to appropriate federal, state and local agencies and to the public. USDQE (1980b)
- 30 It is assumed for FUSRAP that (1) DOE will own and maintain all stabilized, interim, and permanent disposal sites except where affected states agree to accept ownership and custodial responsibilities. (2) All stabilized, interim, and permanent disposal sites will be licensed by NRC. USDQE (1980b)
- 31 DOE will develop its proposals for waste disposal options on a basis of interagency and public review [of preliminary evaluations and conclusions]. USDQE (1980b)
- 32 To ensure long-term institutional control of disposal sites, private ownership is not acceptable. USDQE (1980b)
- 33 After January 1, 1986 any [regional disposal] compact may restrict the use of the regional disposal facilities to the disposal of LLRW generated within the region. Lipton (1981)
- 34 Site selection shall be consistent with federal, state, and local laws and regulations. Federal laws include: Clean Air Act, Clean Water Act, Safe Drinking Water Act, NEPA. Falconer et al. (1981)

- 35 Falconer et al. (1981)
The site shall not be within areas protected from such use by federal, state, or local laws and regulations. Federal laws include: Wilderness Act of 1964, Wild and Scenic Rivers Act of 1968, National Wildlife Refuge Act of 1966, National Parks National Historical Preservation Act of 1966, Archaeological and Historical Preservation Act of 1974, Heritage Conservation and Recreation Service.
- 36 USDOE (1981a)
Options available to states for site selection responsibility range from an active role in which the state retains all authority to an oversight role in which authority is delegated to one or more contractors, a mix of retained and delegated authority may be practical.
- 37 USDOE (1981a)
An agreement state could be placed in a self-regulating situation if it is also operating the site, [but] division or regulatory and operating responsibility between separate state agencies may avoid that potential conflict of interest.
- 38 USDOE (1981a)
Federal agency responsibilities are:
NRC-establish performance and licensing criteria, approve licenses, regulate operation of LLWDF.
DOE-assist in proving state and regional solutions for adequate waste disposal, providing technical and other resources to the states.
DOT-regulate transportation of LLW, advise states on transportation requirements.
USGS-advise and assist other agencies and the states, provide objective technical assessments of geologic and hydrologic aspects of the sites.
- 39 USDOE (1981b)
Twenty six Agreement States regulate all commercial LLW generators [within their boundaries] except power plants. They also license users of sealed sources and waste disposal sites.
- 40 USDOE (1981b)
DOE and DOD activities are not regulated by NRC or Agreement States; defense waste disposal falls under the purview of DOE.
- 41 USDOE (1981b)
Public Law 96-573 (LLRW Policy Act) designates states as responsible for disposing of waste generated within their borders. States will need to decide whether to provide for waste disposal in their state or seek agreements for regional disposal.
- 42 USDOE (1981b)
Voters in one state recently passed an initiative to ban the disposal of low-level nonmedical wastes from out of state. This classification by source has national impact on waste management practices.
- 43 USDOE (1981b)
Most states impose restrictions such as monthly volume limits, predisposal inspection, prohibitions against certain types of waste based on waste form (e.g. organic liquids), waste source (e.g. medical vs. nonmedical), or location of the generator (in state vs. out of state).
- 44 USDOE (1981b)
The lack of comprehensive [waste] classification system would hinder formation of interstate compacts, thus impeding development of regional disposal sites.

- 45 USDOE (1981b)
One set of regulations for both transportation and disposal would in the long run probably require Congressional action. Memoranda of understanding have been considered in nature.
- 46 USDOE (1981b)
Regional compacts must be approved by Congress and reviewed every 5 years.
- 47 USNRC (1980b)
Title to the byproduct material and land used for [its] disposal are essential to ensure a long-term stability of the [disposal] site shall be transferred to the United States or to the state, at the option of the state.
- 48 Murphy and Holter (1980)
Although agreement states can presumably adopt regulations applicable to decommissioning of LLW burial grounds, none appear to have done so. Nor is decommissioning explicitly treated in current license agreements.
- 49 Wilson (1978)
The Stark County Planning Commission of Stark County Illinois is opposed to the reopening of the Sheffield Dump Site, which is located in nearby Bureau County Illinois, and feels that it should be closed permanently. It will be our intent to suggest to the Stark County Zoning Board regulations forbidding the development of such dump sites in Stark County.
- 50 Wilson (1978)
The significant issues are: dump sites should not be located in heavily populated areas; should not be located in or near land which is used for crops or pasture; dump sites should be covered by more than 30 feet of earth due to percolation which occurs because of freezing and thawing; local opinion must be solicited if a dump is proposed to be located in a given area; and local zoning laws should be adhered to.
- 51 Valore and Lawmarsh (1978)
The extent to which each state should be responsible for its own radioactive waste is a political issue which will only be solved by the political process as the exigencies of the situation require. In any case, the licensing and monitoring of waste disposal sites should remain within the province of the Federal Government. Independent monitoring of such sites can and should be carried out by state and local authorities.
- 52 Lash (1979)
NRC recommends the transfer of regulatory authority over long-lived wastes from the states to NRC.
- 53 Lash (1979)
It is far from clear that every state has sites that will safely store low-level wastes, and proliferation of sites to 50 is undesirable from a managerial point of view. Sources of LLW cover a wide variety of activities, and the people who benefit from them are not always residents of states in which these activities occur. A state should not necessarily bear the major responsibility for disposal of wastes produced within its borders.
- 54 Shapiro (1981)
By 1978, with more than three million cubic feet of material, Sheffield was filled to capacity. The facility could have expanded, but Nuclear Engineering's attempt to have adjoining land zoned was denied by the county Board of Supervisors, and, as at West Valley, the operator is now trying to turn the buried waste over to state control.

55 Whether or not state regulation would be eventually declared federally preempted, the governor, legislature, or people of a state can in many ways resist activity within the state's borders that is authorized or directed by the federal government. In this regard, states have at their disposal several legal means to apply pressure on any federal project that does not meet state approval.

Hebert et al. (1978)

56 USDOE (1981d)

Every kind of conflict of authority and interest which could arise over radwaste transportation is present, full blown, in the future disposal of spent fuel for the plants planned by Long Island Lighting Co. (LILCO). The only connection to the mainland is through New York City. NYC has banned transit through it of radioactive material, save under Certificate of Emergency from its Department of Health (which has been granted only for medical LLW and material). Brookhaven National Laboratory, which has a reactor, has identified ferrying across Long Island Sound as an option. New London, Conn., has enacted a ban similar to NYC's. LILCO and the federal government unsuccessfully sought an injunction against the NYC ban, the case was remanded for administrative action, and DOT found the ban to be inconsistent with its existing regulations. DOT is developing rules for routing of radwaste transportation. NRC's proposed rules (June 1979) state that cities should be avoided where possible, but "avoidability" is open to dispute. If DOT's rules favor the NYC ban, LILCO will probably challenge in the courts. If DOT's rules favor LILCO, NYC will likely challenge DOT's constitutional right to rule on the matter at all. It may well take the U.S. Supreme Court to resolve the issues. The U.S. Coast Guard could also be involved, since it regulates transport over water, but that is not expected to be a significant complication.

USDOE (1981d)

57 When Bear Creek was approved, developers needed only the mineral rights to land in order to bury uranium mill tailings. Now, under the Uranium Mill Tailings Radiation Control Act of 1978, they must either control title to the surface on which they deposit their tailings, or construct their disposal facilities on land controlled by a government entity. In Bear Creek's case, the surface of the tailings site is controlled primarily by the State of Wyoming and to a lesser extent by the U.S. Forest Service. Following reclamation of the tailings area and termination of the Bear Creek Project, title will either be retained by these entities or wholly transferred to the federal government.

USDOE (1981d)

58 A more serious problem arose because various Indian groups declared that sacred burial grounds and cultural resources existed in the area. They insisted that these sites could not be touched under any condition. Unfortunately, not only would the trenching activities impact on these sites, but these sites are often times disturbed by the archaeologists engaged in data recovery operations. The problem with the Indian cultural sites was unmitigatable because the Indians demanded that the site not be touched. Because the seismic study required extensive trenching activity, impacts were inevitable. Since there are no regulations governing these types of problems the battle had to be fought in the courts. The LNG Terminal Associates won, but at the expense of delays to the seismic studies. There was also some problem with acquiring a State archaeologist to monitor and recover the data since the Indian groups requested that no archaeologist participate. Many archaeologists honored the Indian's request; however, a qualified individual was finally found.

59 National Acad. of Sci. (1979)
The federal government should accept full responsibility for any radioactive wastes in existence, leaving the question of joint state-federal responsibility to be resolved for wastes generated in the future.

A.1.3 General Legal, Regulatory, and Philosophical Issues

- 1 USEPA (1977b)
For what length of time should isolation be assured for surface burial of radioactive waste? Should institutions be relied upon to maintain the integrity of sites during this period?
- 2 USEPA (1978)
What should the regulatory agency's (EPA, etc.) format be for broader participation by the public in the development of rulemaking consideration?
- 3 USEPA (1978)
Reliance on institutional control of disposed waste should be minimized. Primary reliance should be placed on engineered and natural barriers to protect the environment and public health.
- 4 USEPA (1978)
Institutional control of waste disposal shall cease when there is no longer any need to restrict land use.
- 5 USDOE (1979)
For radwaste management, institutional and political issues will be more difficult to achieve than solutions to the remaining technical problems.
- 6 USDOE (1979)
Develop acceptable (state/federal basis) criteria for evaluating radwaste management activities (R&D, siting, etc.).
- 7 USDOE (1979)
Develop a mechanism for waste-disposal planning which will represent all interests and concerns at the state and local levels.
- 8 USDOE (1979)
Long-term surveillance responsibility needs to be established for remedial actions required at abandoned sites which do not meet current standards for unrestricted use.
- 9 USDOE (1979)
The overall public participation process should be expanded so as to aid development of government waste-disposal policy.
- 10 USDOE (1979)
The federal government credibility is in question on nuclear waste-disposal management and other national issues.
- 11 Compt. Gen. of U. S. (1980)
Which, if any, of existing DOE and commercial LLW sites could be used for FUSRAP? (GAO is not convinced by DOE arguments.) Include possible re-opening of closed sites.

- 12 Inspection and enforcement, not regulations, are the problems in waste disposal. [D.L. Ray] USDOE (1980c)
- 13 Regional disposal sites for remedial action wastes is a preferred disposal option. USDOE (1980b)
- 14 Scoping identification of alternative remedial actions and candidate disposal sites will involve affected state and local authorities, EPA, NRC and other appropriate agencies. The principal issues to be examined will be identified, and responsibilities, schedule, and interfaces for conducting necessary studies will be agreed upon. USDOE (1980b)
- 15 Type of disposal-site ownership, based on either government financing or commercial rates [is a key issue affecting costs and schedule]. USDOE (1980b)
- 16 The major issues to be resolved before establishing and operating a disposal facility are: What type of system is required, who will select the location, who will prepare and submit the license application, who will operate the site, who will own the land and assume long-term responsibility. USDOE (1981a)
- 17 Classification by total hazard is deemed desirable by the states, which [should] enhance development of regional compact and disposal sites, and it should achieve greater protection of the public than any alternative classification scheme. However, costs of waste management and disposal would increase substantially, and regulation development and enforcement would significantly impact on regulatory agencies. USDOE (1981b)
- 18 Formulation of new policy to allow release of solid LLW would be a significant undertaking involving every sector of society concerned with LLW. Establishing maximum permissible concentrations for release would require an EIS under NEPA. USDOE (1981b)
- 19 The pertinent regulatory concerns are:
1. Adequacy of published regulations, stated philosophies, and licensing requirements to provide a framework of regulatory controls covering health and safety, site selection, and operational criteria.
2. Accident response procedures.
3. Environmental protection standards.
4. State vs. federal ownership and control of disposal sites.
5. Long-term monitoring or surveillance responsibilities.
6. Institutional stability. USDOE (1981b)
- 20 A major need in shallow land burial of low-level radioactive wastes is a formal policy consisting of a written set of goals, objectives, criteria, performance standards, measures of performance, and codes of practice. Jacobs et al. (1980)
- 21 Institutional Controls:
Domestic Regulatory Controls:
Adequacy of public regulations stated philosophies and licensing requirements to provide framework of regulatory controls covering health and safety, site selection, and operational criteria. Accident response procedures. Environmental protection standards. State versus federal ownership and control of disposal sites. Long-term monitoring and surveillance responsibilities. Macbeth et al. (1979)
- 22 Institutional Controls:
International Controls:
Appropriateness of international involvement in territorial disposal operations. Established standards and guidelines. International agreements for world-wide disposal criteria and practices. Macbeth et al. (1979)
- 23 Issues concerning administration of a site that need to be resolved include the following. Should the site be operated by an authority of all states designated in the region? Should a public agency operate the site or should private industry be the operator? Should the home state contract with an industry and all costs be paid by the users from the participating states? What agreements and control measures on routing of shipments to the site are needed? Indemnification of the home state by participating states - who will be liable? DiSibio (1980)
- 24 Mechanisms for resolving issues of siting, administration and control should include: direction of the organization by the national governor's conference in concert with the three states with commercial sites and experience; data provided by NRC and agreement states on volume, density and future generation of LLW; standards and organization from USGA and EPA; research and development support from DOE; shipment and routing control by DOE and EPA. Site administration should be left to participating states. DiSibio (1980)
- 25 A major institutional issue for uranium milling that is also relevant for FUSRAP waste disposal is the need for land use controls and site monitoring at disposal sites. USHRC (1980a)
- 26 Institutional controls, such as record keeping, maintenance, and land-use restrictions, can provide greater protection than the standards require, but they are unreliable as the primary control over one thousand years. Though institutional controls can be helpful, physical disposal methods are necessary. USEPA (1980d)
- 27 The principal criterion for measuring the adequacy of alternative institutional arrangements is:
- Performance. The system must carry out the technological tasks for which it is responsible. Because it is not possible to know with certainty how institutions will perform, some additional criteria is useful:
- Accountability. It is important that a system be instituted to assure the accountability of the organizations to the public.
- Stability or durability. The organizations should be able to survive for the length of time necessary. (which varies according to the task for which they are responsible).
- Adaptability. Since the organizations endure through several generations, they should be able to adapt to technological change, deal with unforeseen occurrences, and cope with changing political climates.
provide a given level of performance at minimum cost ("cost-effectiveness"), and the cost of waste management should be borne by the users of the power that generated the waste. Hebert et al. (1978)

28

Rotow et al. (1979)

As the attached NRDC Report shows, we believe a path more responsive to EPA's legislated mandate and to public perception is to approach waste management criteria from a perspective that uses environmental non-degradation as a fundamental goal.

29

Rotow et al. (1979)

Protection requirements (for people and for the environment) should not be based primarily on assessment of risk to individuals and populations; rather, they should be based on societal evaluations of assessments of risk to individuals and populations.

30

Havey (1979)

The following principles might better serve [i.e., better than comparison to natural background or than the NRDC'S criteria] as guidance in the formulation of social policies for radiation health protection:

- (1) Any involuntary risks imposed by social policies for radiation protection must be congruent with, must not be in excess of, and may be reasonably less than, those involuntary risks imposed by the wide variations in naturally occurring toxic elements and harmful effects from our natural environment.
- (2) There must be evidence that basic goods and essential benefits cannot be more satisfactorily obtained through other alternative means which entail fewer risks.
- (3) The basic goods and essential benefits must be demonstrated or virtually assured, and they should outweigh the possibility of basic harm to human well-being.

A.2 RELEASES AND THEIR CONSEQUENCES

A.2.1 Release Mechanisms and Dispersion

- 1 A waste-disposal risk assessment should consider movement of radioactivity through the environment and the resultant human uptake, taking into account the effect of assumptions of future climate, land use, and demography. USEPA (1978)
- 2 A waste disposal risk assessment should address mechanisms of local release of wastes from the disposal site and the likelihood of such release. USEPA (1978)
- 3 Reliance on institutional control of disposed waste should be minimized: Primary reliance should be placed on engineered and natural barriers to protect the environment and public health. USEPA (1978)
- 4 Disposal site owner/operator should provide a description of the rate of mass transport of leachate from the disposal facility. USEPA (1980c)
- 5 Disposal site owner/operator should provide a description of the earth materials above the zone of saturation through which the leachate released from the facility will migrate. USEPA (1980c)
- 6 Landfill-closure design and post-closure care must consider the mobility and expected rate of migration of the disposed waste. USEPA (1981d)
- 7 The comment "Studies to date conclude that (disposal waste) migration does not pose any present threat to public health and safety" downplays the risk that such a threat could develop in the future. USDOE (1979)
- 8 Identification and study of organic materials that influence release and migration of radionuclides from the disposed wastes [is desirable]. Levin (1980)
- 9 Design of engineered barriers to inhibit radionuclide migration [is desirable]. Levin (1980)
- 10 Containment (waste stays put) should be distinguished from isolation (no human or other intrusion likely). Macbeth et al. (1978)
- 11 Deeper land burial LB, with final cover of 10 to 20 m of clean soil, would largely avoid certain shallow land burial problems: inadvertent encounter with waste, water infiltration, erosion to expose waste before it decays to innocuous residual activity. Macbeth et al. (1978)
- 12 Burial trenches are or could be designed to contain critical nuclides for several hundred years. Macbeth et al. (1978)
- 13 The major question regarding disposal in manmade structures is its ability to confine the waste under all conditions for the time periods required. Macbeth et al. (1978)
- 14 Once waste reaches the surface it can be quickly transported off-site by rainfall or by wind. Lipton (1981)
- 15 The site selection process should include sufficient detailed information on site geology, hydrology, and meteorology to identify and evaluate all potential migration pathways. Lipton (1981)
- 16 Numerous models [for pathways and migration rates] are available, although inadequate for complete determination, particularly for media with anomalies such as fractures. Lipton (1981)
- 17 The numbers and placement of monitoring devices should be based both on available information on potential migration pathways and on cost-benefit considerations. Lipton (1981)
- 18 Characteristics of earth materials and groundwater chemistry at the site shall favor retention of radionuclides and other contaminants. The rate of subsurface migration depends primarily on the mineralogy and surface area of geologic material, groundwater chemistry, and groundwater flow rate. Falconer et al. (1981)
- 19 Evaluation of the technical feasibility of Intermediate Depth Burial [is a priority technical issue]. In comparison to SLB, for example, there is increased isolation of waste, greater operational costs, decreased distance to water table. Deichman (1979)
- 20 The issue of environmental releases deserves a high priority. Central is the lack of consistency between current requirements for disposal of LLW in solid form and regulations allowing certain concentrations of liquid and gaseous radioactive materials to be released to the environment. USDOE (1981b)
- 21 The principle of dilution and dispersion has long been an accepted treatment for certain pollutants, and is the basis of current practice [when] releases of radioactive liquids and gases [is allowed]. USDOE (1981b)

- 22 USDOE (1981b)
Current practice does not allow the release of solid radioactive waste into the environment. Items with surface activity can be decontaminated and recycled, but items with internal contamination from neutron activation must be shipped to disposal sites whatever their potential of hazard.
- 23 Adam and Rogers (1978)
The most important mechanism by which individuals can be exposed to radioactivity from waste are: (1) Inhalation of dust by reclaimer digging in the waste, or by residents on the reclaimed site, (2) Ingestion of water from a well dug by reclaimer, (3) Consumption of food grown in a garden containing contaminated soil, (4) Direct exposure to workers or residents from gamma radiation, (5) Atmospheric transport to individuals via continuous releases and accidental releases, (6) Groundwater migration to a resource waterway, (7) Surface erosion to a resource waterway.
- 24 Adam and Rogers (1978)
Are there any dispersion pathways other than the seven considered in the analysis of a reference containment facility (dust inhalation from onsite activities, water ingestion from onsite well, consumption of food grown onsite, direct gamma exposure, atmospheric transport of continuous or accidental releases, groundwater migration to a surface waterway, or surface erosion) that might lead to nonnegligible radiation exposure?
- 25 Adam and Rogers (1978)
Are the calculational models that have been developed and used for estimating the radiation hazards from LLW disposal due to: (1) inhalation of dust by a reclaimer, (2) well water reclamation events, (3) direct gamma exposure, (4) atmospheric releases of contamination, (5) groundwater migration, (6) ingestion of food produced on a disposal site, and (7) surface erosion reliable and accurate enough to provide a sound basis for estimating the radiological impacts from near-surface disposal of FUSRAP waste?
- 26 Adam and Rogers (1978)
The method of analysis used by Adam and Rogers (1978) for calculating exposure events by different dispersion pathways may be useful for analyzing the exposure events from FUSRAP waste at near-surface disposal sites.
- 27 Adam and Rogers (1978)
The three most important radionuclides for off-site doses at the Hoxey Flats LLW site are H-3, Sr-90 and Pu-239. Different calculations (by NRC, EPA, OH and FB DJ, some of which are upper-bound calculations) of the dose rates from aquatic and airborne pathways differ by an order of magnitude or more (excluding the upper-bound calculations, some of which are several orders of magnitude larger).
- 28 Adam and Rogers (1978)
Items that may warrant further investigation and definition include: (1) a more detailed analysis of deeper burial for certain waste types; (2) clarification of the role of inventory-limited pathways and their application to waste classification; (3) identification of possible synergistic exposure and migration effects; and (4) further investigation of the role of corrosion rates and products in waste mobilization.
- 29 Adam and Rogers (1978)
More information regarding the effect of varying parameters in waste calculations is needed; e.g., varying burial depth, containerization and waste forms.
- 30 Jacobs et al. (1980)
Technical issues related to problems experienced at existing shallow land burial facilities, which need to be resolved by further research and development in order to develop improved management practices and provide information for remedial actions at both closed and currently operating sites, may be grouped into seven major areas: (1) water management; (2) radionuclide migration; (3) waste inventory records; (4) performance monitoring and evaluation; (5) prediction capabilities; (6) space utilization; and (7) management practices.
- 31 Jacobs et al. (1980)
A systematic predictive capability of potential releases from all operations involved in shallow land burial needs to be developed and verified by comparison with past and current performance evaluation. This will require identification and quantification of significant transport pathways and development of an understanding of the specific mechanisms involved. The sub-models used to depict the various pathways should credibly reflect the mechanisms involved and the range of parameters likely to be encountered at specific sites.
- 32 Jacobs et al. (1980)
All operations involved in shallow land burial covering the period from the time of receipt of waste shipments through the time in which radioactive decay reaches innocuous levels, should be reviewed with respect to potential sources and pathways of release.
- 33 Jacobs et al. (1980)
The critical radionuclides in waste should be identified on the basis of such factors as quantities, concentrations, radiotoxicity, environmental mobility and persistence. Potential acute and chronic release mechanisms should be identified and ranges established for their probabilities of occurrence for the time period the waste remains hazardous. Further work should describe and quantify the probable ranges of the rate of environmental transport and exposure for a broad spectrum of pathways. Systematic evaluations for the full chain of considerations would then identify those radionuclides and pathways which are likely to be most important so that emphasis can be placed on their quantification in subsequent research and development.

- 34 Jacobs et al. (1980)
A number of pathways can eventually lead to exposure of man. The more direct pathway of exposure include the use by man or animals of contaminated groundwater for drinking or the uptake of radionuclides from the soil into the food chain. Lateral migration can result in contamination of adjacent groundwater and surface water. If a contaminated region includes a productive aquifer, water uptake for irrigation may result in exposure. A less likely, long-term exposure pathway could result from denudation of the cover formation followed by surface erosion of the contaminated zone by wind and water.
- 35 Jacobs et al. (1980)
Development of mathematical models for radionuclide migration seems to be more advanced than current ability to verify the models with field data. Rates of radionuclide migration in the ground tend to be slow, so more emphasis needs to be placed on systematic measurements of the distribution of radioactivity in close proximity to the burial trenches. This should permit considerably more reliable projections of future behavior of the facility than more remote measurements.
- 36 Jacobs et al. (1980)
Specific items related to radionuclide migration that need additional research and development emphasis include: (1) vapor phase migration and interactions in the ground; (2) measurement and compilation of site-specific geohydrologic parameters; (3) migration of radionuclides through cracks and fissures; (4) effect of biological activity on radionuclide migration; (5) evaluation of long-term chemical changes in the ground; and site-specific measurement of radionuclide migration.
- 37 Jacobs et al. (1980)
Specific items related to predictive capability that need additional research and development emphasis include: (1) systematic evaluation of all significant mechanisms and pathways of radionuclide release and migration; (2) develop quantitative estimates of ranges of probable releases and imports; (3) development of models for vapor phase transports; and (4) verification of models.
- 38 Macbeth et al. (1979)
Initially, hydrologic and geologic site characteristics were relied upon for waste containment. Packaging was provided to meet transportation requirements and for ease of handling, but not relied upon for containment.
- 39 Macbeth et al. (1979)
Although in some cases containment of wastes has been less than initially expected, no large health hazards to members of the public have resulted from waste disposal operations.
- 40 Macbeth et al. (1979)
Exposure pathways used in the analysis by Macbeth et al. (1979) are those found by Adams and Rogers (1978) to be the most significant.
- 41 Macbeth et al. (1979)
Short-term radiological effects include direct gamma exposure to workers and public along transportation routes, accidents causing airborne contamination, and small airborne release in normal operations. The pathways considered most important for comparative analysis are direct exposure to ionizing radiation from waste packages, extremely small ongoing release from contaminated package surfaces, and airborne contamination from accidents or spills.
- 42 Macbeth et al. (1979)
Among the expected radiological impacts of a "reference" SLBF, food pathways yield the most significant long-term effects, while accidental airborne releases lead to the largest short-term effects (see Macbeth 1979, Table 3.6).
- 43 Macbeth et al. (1979)
Deeper burial provides enhanced security as compared to SLB.
- 44 Macbeth et al. (1979)
IDB would provide significantly greater isolation and protection against inadvertent intrusion than SLB. For example, most reclamation activities would not involve excavation to the depth of the waste.
- 45 Macbeth et al. (1979)
Radiological impacts for IDB, as estimated, would be less than for SLB by a factor of 5 to 6. Percolation of surface water down to the waste is retarded, and inhalation and food pathway exposure virtually eliminated.
- 46 Macbeth et al. (1979)
Because deeper burial provides greater isolation of the wastes from the human environment, and because of the possibility of using strip mines or other land unsuitable for more productive use, IDB may be more acceptable to the public than SLB.
- 47 Macbeth et al. (1979)
Analysis of the groundwater pathway for the generic land burial site treats the entire waste inventory as a point source, even for flow to a site boundary well. Hence, the distribution and/or average concentration of activity in the waste has no influence on estimated flows and doses.
- 48 Macbeth et al. (1979)
In analysis for a generic land disposal facility, the standard Gaussian Plume method has been used to model transport of airborne release following a container rupture accident.
- 49 USNRC (1980b)
In selecting among alternative tailings disposal sites or judging the adequacy of existing sites, the extent to which a program meets the broad [NRC] objectives depends on:
• Remoteness from populated areas.
• Immobilization and isolation of contaminants from usable groundwater sources, [as provided by] hydrologic and other natural conditions.
• Potential to minimizing erosion, disturbance.
• Dispersion by natural forces over the long term.

- 50 USNRC (1980b)
Primary emphasis shall be given to long term isolation of tailings or waste as opposed to short term convenience or benefits such as minimization of transportation or land acquisition costs.
- 51 USNRC (1980b)
While the primary method of protecting groundwater shall be isolation of tailings, disposal involving contact with groundwater will be considered provided it is demonstrated that the groundwater will not be degraded from current or potential uses.
- 52 Healy (1980)
The major release mechanisms (and pathways) to man that can occur over time are as follows: erosion and transport to streams (drinking, uptake in fish, irrigation); leaching to aquifer (drinking, irrigation); aquifer to stream (drinking irrigation, fish); intrusion (resuspension); exposure of wastes (resuspension, ingestion in foods). Additional release mechanisms exist, but analysis indicates that, when carried to an extreme, conditions approaching those noted above will be present.
- 53 Healy (1980)
Illustrative limits for Pu-239 at a model burial ground, obtained by analysis of exposure via major pathways, giving type of waste (method of exposure) - Pu-239 concentration limit, are as follows: normal trash with dilution by non-contaminated waste (living on exposed wastes) - 50 nCi/g; contamination uniform through waste, i.e., incinerator trash (living on exposed wastes) - 2 nCi/g; normal trash, nondegradable packages (intrusion) - 3nCi/g; artifacts (intrusion) 60 pCi/cm².
- 54 Deichman (1980)
Near-surface media (e.g., soils) are invariably non-isothermal, nonisotropic, and nonhomogeneous, so that material transport is rarely simple. In partially saturated geohydrologic systems, radionuclide species are typically dissolved in the vapor or solid phase, depending on the burial conditions and the chemical species of the radionuclides. The relative distribution among these phases may change in both time and space. Radionuclides can migrate in either liquid, gas, or solid form. The mechanisms causing migration under complex environmental conditions experienced at burial are not completely understood.
- 55 Deichman (1980)
Models have been developed to evaluate mass and energy balance in the atmosphere and in geohydrologic systems. However, these models do not adequately simulate the migration of radionuclides and water in the geohydrologic system. The inadequacy of simulation is predominantly due to paucity of information concerning the mechanisms influencing transport. Furthermore, most models need to be validated. Quantitative information is needed on the interaction of the waste and the disposal medium to evaluate three-dimensional transport of fluids, gas, particulate matter and radionuclides and for their evaluation using existing predictive models.
- 56 Deichman (1980)
Some radionuclides (e.g., C-14, Ni-59, Ni-63, and Tc-99) have half-lives which are long, relative to the projected period of active maintenance and administrative control of a decommissioned burial site. It is necessary to assess the probability of their transfer in time via various environmental pathways into man. If such studies indicate a significant potential radiation dose is possible, limits should be derived for the concentration and quantities of long-lived radionuclides to be permitted in SLB or IDB.
- 57 IAEA (1981)
Radionuclides present in solid waste may be released to the environment by the following mechanisms: (a) exposure and overland transport of nuclides by normal erosional processes (water and wind), erosional floods, or by erosion following disruption of the landscape earthquakes; (b) transport of dissolved radionuclides by groundwater wells, streams or springs; (c) transport of dissolved radionuclides upward to the soil zone by capillary flow followed by uptake in plants; (d) transport of radionuclides by gases generated by bacterial reduction of organic waste material and containers; (e) dispersal following intrusion by animals or deep rooted plants; (f) intrusion by man; and (g) accidents during handling or disposal operations. The suitability of a site for shallow ground disposal waste is, therefore, dependent upon the extent that the site features are capable of preventing or delaying the occurrence of these mechanisms.
- 58 USNRC (1980a)
A major technical issue for milling that is directly relevant for FUSRAP waste disposal is mill tailings as a long-term waste management problem. Major problems are those of isolating tailings from people for long time periods, control of persistent airborne (particularly radon) and protection of groundwater quality.
- 59 USNRC (1981a)
Disposal [in Part 61] means the isolation of radioactive wastes from the biosphere by emplacement in a land disposal facility.
- 60 USNRC (1981a)
Pathways [to be] analyzed [in license applications] include air, soil, groundwater, surface water, plant uptake, and exhumation by burrowing animals.
- 61 USNRC (1981a)
Migration analysis [in license applications] must identify and differentiate between roles of natural site characteristics and design features in isolating and segregating the wastes.
- 62 USNRC (1981a)
Analysis [in license applications] of long-term stability and of need for postclosure maintenance must rest on analysis of active natural processes such as erosion-mass wasting, slope failure, and adjacent soils, and surface drainage.

- 63 USMRC (1981a)
Primary emphasis in site suitability is on isolation of the waste, and on disposal site features that assure that the long-term performance objectives are met, as opposed to short term convenience or benefits.
- 64 Murphy and Holter (1980)
Exposure pathways that may result from hydrological release mechanisms include:
 . ingestion of water from a well drilled on the burial site into the shale formation below the waste or ingestion of water from a nearby river
 . ingestion of aquatic foods taken from a nearby river contaminated by radionuclides released through the ground water or by overland flow
 . ingestion of crops irrigated with contaminated water taken from the river
 . direct irradiation from crop fields irrigated with contaminated river water and from soil contaminated by overland flow of radionuclides
 . inhalation of resuspended radionuclides deposited on crop fields by irrigation or by overland flow
 . ingestion of foods contaminated by the deposition of resuspended irrigation and overland flow deposits.
- 65 Murphy and Holter (1980)
To determine release conditions for a decommissioned LLW burial ground this study uses the concept of the maximum annual dose to an organ of reference of a maximum-exposed individual. The maximum-exposed individual is assumed to live and work on the decommissioned site, to eat all of his food from crops and animal products grown on the site, and to drink water from a well drilled on the site.
- 66 Murphy and Holter (1980)
It is assumed that a package in which waste is buried will lose its integrity shortly after burial. Therefore, no credit is taken for packaging of the waste.
- 67 Murphy and Holter (1980)
Program objectives for environmental surveillance and records maintenance include:
 . detection of changes in and evaluation of long-term trends of concentrations of radionuclides in the environment, with the intent to detect radionuclide migration and initiate appropriate actions
 . collection of data on the history of contaminants released to the environment, with the intent of discovering previously unconsidered pathways and modes of exposure.
- 68 Murphy and Holter (1980)
Murphy and Holter, in Table 10.1-1, indicate the applicability of 19 identified site/waste stabilization techniques to the control of 12 types of release mechanisms.
- 69 Murphy and Holter (1980)
Effectiveness of nineteen prospective stabilization techniques for control of twelve radionuclide transport mechanisms is rated by Murphy and Holter in Table 10.2-1.

- 70 Murphy and Holter (1980)
Little attention has been given to the verification of transport models by field tests at existing sites. In part, this is because of the lack of an appropriate experimental apparatus for monitoring waste burial sites to assess the influence of environmental factors on radionuclide migration rates.
- 71 Murphy and Holter (1980)
Plant roots, in addition to uptake of radionuclides, are also instrumental in the mechanical breakdown of buried waste and overburden material. Most reports of biological interaction with waste have involved plants.
- A.2.1.1 Leaching to Surface- and Groundwater
- 1 USEPA (1981e)
What level of specificity of information must one have about buried waste in order to predict the rate and quality of leachate produced?
- 2 USEPA (1981e)
What impact does burying different wastes in the same cell have on the reliability of predicting leachate discharge? (How about the same facility?)
- 3 USEPA (1981e)
Is it possible to confidently predict leachate quality by analyzing in detail the fate of a few representative constituents in the buried waste?
- 4 USEPA (1981e)
How sensitive is the prediction of buried-waste leachate volume, generation-rate, and quality to errors in predicting water balance?
- 5 USEPA (1981e)
How sensitive is prediction of buried-waste leachate generation-rate to correct and precise analysis of clay liner materials, waste cells, and the unsaturated zone as to permeability, uniformity, moisture content, clay content, and organic content?
- 6 USEPA (1981e)
With what confidence can one predict when buried waste leachate will emerge (in groundwater, surfacewater)?
- 7 USEPA (1981e)
How well can site physical properties be accounted for in predictions of leachate generation-rate and quality, and how sensitive are such predictions to these properties?
- 8 USEPA (1981e)
What costs and burdens are associated with calculating or estimating (or determining) the effects of site physical properties to the degree necessary to confidently predict leachate generation-rate and quality?

- 9 Given the absence of very (long-term) data, what confidence can be expected that any particular waste management technique will, for a long period of time, result in the predicted buried-waste leachate generation-rate and quality? USEPA (1981e)
- 10 If one ignores all attenuation, how well can one predict the transport of (buried-waste) leachate constituents (to groundwater)? USEPA (1981e)
- 11 How well can one predict the degree of which the (waste-) leachate plume will expand, and concentrations of (migrating) constituents will decrease by virtue of molecular diffusion? USEPA (1981e)
- 12 How well can we predict the degree to which (migrating waste) constituents concentrations will decrease by virtue of mixing with the groundwater? USEPA (1981e)
- 13 To what extent can mitigating mechanisms be expected to cause the decay of (migrating waste) constituent in the saturated (groundwater) zone? USEPA (1981e)
- 14 With what degree of confidence can the attenuation of (migrating waste) constituents by sorption be predicted? USEPA (1981e)
- 15 Are there any mechanisms other than sorption significant enough and predictable enough to be evaluated in predicting attenuation of (migrating waste) constituents? USEPA (1981e)
- 16 Where knowledge of (buried-waste) leachate quality entering the groundwater is highly uncertain, what simplified approaches can be used to characterize plume migration? USEPA (1981e)
- 17 Is it possible to predict the concentration of (migrating waste) constituents in the groundwater even within several orders of magnitude? The single most important factor affecting containment is the degree to which groundwater can contact the waste and cause migration of radionuclides. USEPA (1981e)
- 18 Waste material leached into solution can migrate off-site through three principal pathways: (1) return to the surface through seepage and subsequent surface migration, (2) plant uptake, and (3) transport through groundwater. Lipton (1981)
- 19 Migration through groundwater must be considered [if] waste containers are designed for safety only during transportation and burial. Lipton (1981)
- 20 Retention [of radionuclides] by soil is commonly indexed by the distribution coefficient (Kd), which can be tested in a laboratory but without certainty that the laboratory measurement will be valid under field conditions. Lipton (1981)
- 21 It is expected that tritium, ruthenium-106, and possibly technetium-99 will be the critical radionuclides for groundwater or surface water migration, but any radionuclide present in a trench should be considered capable of migration. Lipton (1981)
- 22 Faster migration can occur through fractures or other anomalies in the [soil] media. Lipton (1981)
- 23 Organic complexes, such as chelating agents, often form highly mobile complexes with normally well-retained radionuclides. Lipton (1981)
- 24 Migration pathways information is site specific, but major pathways are expected to be: through ground or surface water for a humid eastern site, and through wind erosion of backfill for an arid western site. Lipton (1981)
- 25 If [subsurface] fractures are present, fluid loss inhibitions (e.g., grouts) might minimize migration of radionuclides. Deichman (1979)
- 26 Determination of mechanisms controlling water/radionuclide transport in unsaturated zones [is a priority technical issue]. Deichman (1979)
- 27 Determination of the effects of organic and inorganic complexation on transport of radionuclides [is a technical priority issue]: Types and quantities of complexing agents [present] in SLB, their interactions with burial media and their effect on retardation. Deichman (1979)
- 28 Detailed study of sorption mechanisms is particularly important for the more hazardous and long-lived radionuclides, to predict their retardation in geologic formations. Deichman (1979)
- 29 Determination of the effects of soil microorganisms on transport and transformation of radionuclide [is a priority technical issue]: Effects of microbial action on solubility, mobility, and bioavailability of radionuclides. Deichman (1979)

- 30 Soil microorganisms may (1) solubilize chemicals in the soil, (2) transform organic wastes into gases, which may be important for release of gaseous forms of C-14 and tritium, (3) may degrade organo-radionuclide complexes, and (4) may influence bioavailability. Deichman (1979)
- 31 If microorganisms are found to have significant effects on radionuclide transport, then potential effects on such microorganisms of climate change, e.g., due to potential "greenhouse effects", may need to be considered. Deichman (1979)
- 32 Factors typically affecting water and radionuclide transport include: (1) micrometeorology (e.g. precipitation, evaporation, solar radiation, humidity, temperature) and (2) geohydrology (e.g. temperature, humidity, water content, cation-anion water concentration, redox potential, pH). Deichman (1979)
- 33 Because disposal operation have modified the hydrogeological characteristics of the West Valley site, erosion control and water management could pose major long-term problems. USDOE (1981b)
- 34 Leachability of radioactive materials from the package and from the site are not considered [by NRC] the main problem in terms of packaging. Physical stability of [the] waste package [is to be emphasized.]. USDOE (1981b)
- 35 Observations/radionuclide migration (as of 1978) at 6 commercial sites (Richland, WA, Beatty, NV, Sheffield, IL, Morehead, KY, Barnwell, SC, West Valley, NY) and 5 DOE sites (Hanford, WA, INEL, ID, Los Alamos, NM, Oak Ridge, TN, Savannah River, SC) revealed migration by water mechanisms (surface water or groundwater) at 6 sites and by uptake through deep rooted plants at one site. These observations suggest that, in the near term, the water pathway is the most important, plant uptake can be important, and the other near-term mechanisms that might lead to exposure of the public are less important. Adam and Rogers (1978)
- 36 Once radionuclides have been leached from the waste trenches and have begun migrating through the ground, the opportunity for control has been greatly diminished. Buffer zones between the actual burial trenches and the site perimeter would increase the opportunity for detection and control of radionuclide migration. Jacobs et al. (1980)
- 37 After wastes have been emplaced in trenches, the geologic formation is considered the primary barrier to radionuclide migration. Water is the principal vehicle for radionuclide transport; thus knowledge of the direction, depth of water table, flow paths, rate of movement, and dispersion of water coupled with the mechanisms and degree of interactions of specific radionuclides with the formation are required to understand radionuclide migration. Jacobs et al. (1980)
- 38 Ion exchange is one of the major interaction of radionuclides with the geologic formation. However, the presence of fissures in the geologic unit may short circuit opportunities for ion exchange of radionuclides mobilized during leaching by infiltrating water. Mechanisms of interaction other than ion exchange may predominate and they are not always well understood. Chemical precipitation and filtration, mineral replacement, surface exchange reactions, and physical adsorption are other important interactions which have been studied. In some cases even the physical characteristics and the direction of the pathway is not clearly defined. Jacobs et al. (1980)
- 39 The USGS has expressed the opinion that additional information on ion exchange capacity is needed for all sites. Such information may be useful, but would provide only a portion of that needed for understanding interactions and migration of radionuclides in the ground. Jacobs et al. (1980)
- 40 There has not been sufficient attention given to development of a systematic predictive capability for shallow land burial operations. Most of the releases that have been detected have been related to groundwater migration and were unexpected largely because of a lack of understanding of both the chemical and hydrological mechanisms affecting radionuclide behavior. Modeling efforts to predict radionuclide behavior in the ground have had limited success because they have assumed ideal behavior of solutes in flowing systems which do not adequately simulate the actual chemical and hydrogeological system. Also, little attention has been given to modeling vapor transport, chemical precipitation, filtration, and other mechanisms of radionuclide translocation. Jacobs et al. (1980)
- 41 The major vehicle for transport of radionuclides in the ground is convective movement of groundwater. When water is the transporting vehicle, one must have knowledge of the direction, flow path, rate of movement, and dispersion as well as the mechanism and degree of interactions of specific radionuclides with the information in order to predict radionuclide migration. In absence of moving groundwater the rates of movement of nongaseous radionuclides by molecular or ionic diffusion are very small. Jacobs et al. (1980)
- 42 The major reaction of radionuclides with minerals in the ground is usually cation exchange. This can be an important means of removing dissolved salts from solutions as the salts percolate through the ground. Ion exchange is particularly characteristic of clay minerals and zeolites because their small particles give rise to large specific surfaces which are available for geochemical reactions. The presence of fissures in the geologic unit may reduce the efficiency of contact between the solute in the moving water and the earth material and reduce the degree of interaction. Jacobs et al. (1980)
- 43 The elucidation of the effect of chemical conditions on the chemical and physical properties of specific radionuclides so that the mechanism and degree of their interactions in the ground can be predicted for the spectrum of conditions likely to be encountered in shallow land burial conditions is an important technical issue. Jacobs et al. (1980)

- 44 Jacobs et al. (1980)
Conditions, factors and properties that are important for predicting the hydrogeological dispersion of radionuclides through the ground include:
the selectivity factor, the exchange capacity, the concentrations of competing cations, the crystal structure of the mineral and nature of the exchanger surface, the pH of the system and buffer properties of the soil, oxidation-reduction conditions, physical adsorption characteristics, the occurrence of organic or inorganic ligands that might lead to the formation of stable complexes which are less subject to chemical or physical adsorption, and biological activity that can lead to the formation of stable complexes.
- 45 Jacobs et al. (1980)
Physical factors, such as: physical transport of fine particles, flow through fissures and channels, degree of saturation and vapor phase transport, can have a major influence on the degree of interaction between radionuclides and the geologic media into which they are disposed. These factors need to be thoroughly understood in order to enable predictions of the mobility of radionuclides from contained waste through the ground.
- 46 Jacobs et al. (1980)
Laboratory studies are needed on: (1) the effect of degree of saturation on radionuclide adsorption; (2) physical transport of fine particles through porous and channeled media; (3) sorption of solutes from solutions flowing through fissures and channels; and (4) vapor transport of radionuclides.
- 47 Jacobs et al. (1980)
The migration of radionuclides in the ground is difficult to simulate under laboratory conditions because a large number of factors may affect radionuclide movement and dispersion. Generic measurement should be conducted using geologic materials and chemical conditions representative of specific sites. Even these precautions are not adequate to fully simulate field conditions as the parameters affecting migration may vary both in time and in space.
- 48 Jacobs et al. (1980)
Available information on site-specific adsorption coefficients for radionuclides of significance in shallow land burial operations should be obtained from measurements made under conditions simulating those anticipated at the site and compiled in a standardized format.
- 49 Jacobs et al. (1980)
Information on the actual migration of radionuclides under field conditions to verify the understanding of the mechanisms of radionuclide migration and predictive models should be collected. Radionuclides moving under field conditions are subject to many more influences than can be simulated in the laboratory. Hydrodynamic dispersion is usually orders of magnitude greater than that measured under laboratory conditions. The presence of fissures, channels, and zones of widely divergent permeability can have a major influence on the movement of water and its solutes. Also, the degree of interaction between the waste solution and the information may be much less than that experienced in the laboratory.
- 50 Jacobs et al. (1980)
After wastes have been emplaced in trenches, the geologic formation is considered to be the primary barrier to radionuclide formation. Water is the principal vehicle for radionuclide transport, and most efforts in developing predictive models for radionuclide movement from burial grounds have involved modeling of groundwater and solute movement. Most models have been based on ideal behavior of ion exchange in groundwater flow systems which can be described in simple mathematical terms. Less attention has been given to vapor transport and other mechanisms of radionuclide translocation.
- 51 Macbeth et al. (1979)
Two groundwater pathways involving leaching and migration from the waste (at an SLBF) have been analyzed: drinking from a well adjacent to the site, and drinking from a nearby stream supplied by an aquifer underlying the site. (See Macbeth 1979, Table 3.4)
- 52 Deichman (1980)
Many organic chemicals are complexing agents which can affect the leachability, solubility, and movement of radionuclides and toxic heavy metals. Inorganic complexes may also be formed and play an important role under appropriate chemical conditions. Knowledge of the types and quantities of complexing agents present, the radionuclide complexes present in trench leachates and within geologic formations, and the mechanisms and extent of interaction of these complexes with the media are needed in order to predict and compare the transport of radionuclides through the ground.
- 53 Deichman (1980)
The mechanisms and degree of interaction between radionuclides in groundwater and soil materials depend to a great extent on the predominant chemical and physical forms of the radionuclides in the waste and in the receiving geologic media. The chemical and physical forms are affected by a number of chemical conditions (e.g., electrolyte concentration, oxidation-reduction conditions, pH, presence of complexing agents) which may be variable in both time and space.
- 54 Deichman (1980)
Sorption coefficients provide an index of the degree of interaction between the radionuclide and the soil material and are affected by a number of parameters. Sorption coefficients should be determined using soil materials and groundwater as they actually exist at specific sites. Parameters affecting sorption coefficients should be evaluated.
- 55 Deichman (1980)
Measurement of sorption coefficients is not sufficient to characterize the mechanisms of the interaction and thus does not provide an adequate basis for predicting radionuclide retardation in the formation. This requires detailed studies of the mechanisms of the interaction and retardation mechanisms; such studies are particularly important for the more hazardous and long-lived radionuclides.

- 56 Deichman (1980)
Soil microorganisms are known to solubilize various chemical elements in the soil by production of organic and mineral acids and other byproducts which may form complexes with radionuclides or may alter the chemical conditions of the solution, such as pH, which affect solubility. Soil microorganisms are also capable of transforming organic wastes into gaseous products. Conversely, microorganisms may degrade organic material, reducing organo-radionuclide complexation and enhancing the retardation of the radionuclides. Chemical and physical changes mediated by soil microorganisms may influence the bioavailability of radionuclides.
- 57 Deichman (1980)
Sampling should be conducted at selected disposal sites to identify and quantify the soil microorganisms present. Laboratory studies should be conducted using soil materials and trench leachates from selected sites inoculated with typical soil microorganisms to identify the reaction mechanisms of microorganisms with radionuclides. Products of microbial interaction with the wastes should be identified to evaluate the potential effects on radionuclide migration and bioavailability.
- 58 Deichman (1980)
Performance assessment of a burial requires field operational analytical systems capable of measuring water and radionuclide transport in the geohydrologic and atmospheric systems. Factors typically affecting water and radionuclide transport include: (1) micrometeorology (e.g., precipitation, evaporation, solar radiation, humidity, temperature), and (2) geohydrology (e.g., temperature, humidity, water content, cation-anion water concentration, redox potential, pH). These parameters are interactive within a complex three-dimensional continuum consisting of the waste burial formation and the atmosphere.
- 59 USNRC (1981a)
[The] two primary safety objectives [are]: prevention of migration of radionuclides, primarily through groundwater, and prevention of exposure to inadvertent intruders.
- 60 USNRC (1981a)
Concentrations of radioactive materials in groundwater must not exceed the maximum containment levels established in the National Primary Drinking Water Standards at the nearest public drinking water supply (a limit of 10 pCi/l above background must be used for uranium and thorium).
- 61 USNRC (1981a)
Upstream drainage areas must be minimized.
- 62 USNRC (1981a)
[There must be] sufficient depth to the water table that groundwater intrusion, perennial or otherwise-into the waste will not occur. Exceptions will be considered if it can be shown conclusively that the predominant means of radionuclide movement is diffusion slow enough to meet the performance objectives.

- 63 USNRC (1981a)
Covers must be designed to prevent water infiltration, to direct percolating or surface water away from the waste and to resist degradation by surface geologic processes and biotic activity.
- 64 Murphy and Holter (1980)
Many uncertainties exist in the parameter values used with the HMT model to simulate radionuclide migration via the groundwater pathway. Order of magnitude uncertainties exist in values for soil permeability, dispersion coefficients, distribution coefficients (Kd), and leach times.
- 65 Murphy and Holter (1980)
The conclusion of the Argonne study on migration in aqueous solution-rock systems of migrating nuclides was that the behavior of migrating nuclides in these experiments could not be accurately described by models that predict a single migration rate based on simple absorption properties and local chemical equilibrium. A dispersive model of fluid flow was needed, and models of nuclide migration need to provide for the reaction of individual nuclides.
- #### A.2.1.2 Diffusion of Gases (Primarily Radon)
- 1 USEPA (1977b)
Should radon exhalation from low-level natural radioactivity disposal sites be controlled, and if so, how?
- 2 USEPA (1981e)
What level of specificity of information must one have about the buried waste in order to predict the generation-rate and concentration of gaseous emissions from the burial site?
- 3 USEPA (1981e)
With what confidence can one predict upward migration of volatile constituents through the buried waste itself?
- 4 USEPA (1981e)
How good is the present state-of-the-art for monitoring and modeling emission (and migration) rates of volatile compounds (and gaseous materials) from land disposal facilities?
- 5 USEPA (1981e)
What level of specificity of information must one have about (buried-) waste constituents in order to predict air dispersion (data)?
- 6 USDOE (1980b)
Radium contamination is a major health concern because radium decays to radon, which diffuses into the air and which decays to radioactive solid materials.

- 7 Chemical reactions in the burial trenches leading to formation of radioactive gas should be considered, but there is no indication that this [is a] pathway with significant potential health hazard. Lipton (1981)
 - 8 Transport of vapor phase tritium through joints and porous zones has been observed. Lipton (1981)
 - 9 The increased depth of disposal [in IDB as compared to SLB] may be especially important [when] formation of gases containing radionuclide is a concern. Deichman (1979)
 - 10 Soil microorganisms may (1) solubilize chemicals in the soil, (2) transform organic wastes into gases, which may be important for release of gaseous forms of C-14 and tritium, (3) may degrade organo-radionuclide complexes, and (4) may influence bioavailability. Deichman (1979)
 - 11 The emission of radon gas is one of the more significant concerns associated with waste that contains U-238 (e.g., FUSRAP waste). Adam and Rogers (1978)
 - 12 The critical nuclide and pathway for low-specific-activity solids such as mill tailings and coal ash is the radon reclamation scenario (inhalation of radon by a reclaimer, e.g., by someone living in a house built on the site). The impact from this exposure event can be reduced by two orders of magnitude by burying the coal ash or tailings sufficiently deep to preclude exposures to unsuspecting reclaimers (about 10 m). Adam and Rogers (1978)
 - 13 There has not been sufficient attention given to development of a systematic predictive capability for shallow land burial operations. Most of the releases that have been detected have been related to groundwater migration and were unexpected largely because of a lack of understanding of both the chemical and hydrological mechanisms affecting radionuclide behavior. Modeling efforts to predict radionuclide behavior in the ground have had limited success because they have assumed ideal behavior of solutes in flowing systems which do not adequately simulate the actual chemical and hydrogeological system. Also, little attention has been given to modeling vapor transport, chemical precipitation, filtration, and other mechanisms of radionuclide translocation. Jacobs et al. (1980)
 - 14 Gaseous radionuclides may move appreciably due to molecular diffusion. Radon and tritium may be expected to migrate significantly in the vapor phase. Carbon-14, in the form of carbon dioxide or short chain hydrocarbons may also move in the vapor phase. The magnitude of such transport should be established by field measurements. Jacobs et al. (1980)
 - 15 After wastes have been emplaced in trenches, the geologic formation is considered to be the primary barrier to radionuclide formation. Water is the principal vehicle for radionuclide transport, and most efforts in developing predictive models for radionuclide movement from burial grounds have involved modeling of groundwater and solute movement. Most models have been based on ideal behavior of ion exchange in groundwater flow systems which can be described in simple mathematical terms. Less attention has been given to vapor transport and other mechanisms of radionuclide translocation. Jacobs et al. (1980)
 - 16 Sufficient earth cover, but not less than three meters, shall be placed over tailings and wastes to reduce surface exhalation of radon to less than two picocuries per square meter per second. USNRC (1980b)
 - 17 The standards limit release of radon gas to the air from disposed tailings to 2 pCi/m²/s, about twice the average of normal soils. USEPA (1980d)
 - 18 Techniques which control radon releases reasonably well and have lasting effectiveness will essentially control airborne particles and direct gamma radiation completely. USEPA (1980d)
 - 19 The radionuclide Ra226 presents a unique problem in determining site release conditions and requires separate consideration. The Rn222 daughter is a noble gas and does not bind chemically or physically to the soil. Murphy and Holter (1980)
- ### A.2.1.3 Erosion and Windblown Dispersion
- 1 Migration pathways information is site specific, but major pathways are expected to be: through ground or surface water for a humid eastern site, and through wind erosion of backfill for an arid western site. Lipton (1981)
 - 2 Development and evaluating erosion and intrusion control barriers [is a priority technical issue]. [It must be] consistent with abiotic, edaphic, and biotic conditions, and stable over long periods of time. Deichman (1979)
 - 3 Because disposal operation have modified the hydrogeological characteristics of the West Valley site, erosion control and water management could pose major long-term problems. USDOE (1981b)
 - 4 Trench caps have eroded at Maxey Flats, West Valley, LASL, and ORNL and periodic maintenance is required. It has been suggested that high velocity winds at burial sites in arid climates might result in removal of significant amounts of trench cover. Jacobs et al. (1980)

5 Jacobs et al. (1980)
In evaluating erosion control measures, consideration should be given to their ability to remain stable over long periods of time and to provide protection against intrusion by deep-rooted plants and by small burrowing animals as well as their effectiveness in providing short-term erosion control.

6 Jacobs et al. (1980)
Over long time periods, say several millennia, even the solid matrix can move significantly because of erosion or tectonic events.

7 Deichman (1980)
Erosion and intrusion control barriers should use techniques (e.g., natural vegetation and/or natural materials barriers) that are resistant to water and wind erosion, effective in reducing infiltration of precipitation, stable over long periods of time, and obstructive to burrowing animals.

8 USHRC (1981a)
Covers must be designed to prevent water infiltration, to direct percolating or surface water away from the waste and to resist degradation by surface geologic processes and biotic activity.

9 USHRC (1981a)
Surface features must direct water drainage away from disposal units at velocities and gradients which will not result in erosion requiring future active maintenance.

10 Lester et al. (1981)
Significant variables of note included weather pattern (dryness, wetness, wind velocity) agriculture in the air path, nuclide quantity in the water path (held constant in the air path), and stack height in the air path. Interactions in the air path included weather (wind and rain) with cap erodibility (geometry of cap), soil size with burial depth, soil size with site wind resistance and burial depth with soil column retardation factor.

A.2.1.4 Human Intrusion

1 Falconer et al. (1981)
The site shall be selected with consideration given to current and projected population distributions. (Effects of accidental and chronic radiation releases, likelihood of human intrusion, etc.)

2 Deichman (1979)
Development and evaluating erosion and intrusion control barriers [is a priority technical issue]. [It must be] consistent with abiotic, edaphic, and biotic conditions, and stable over long periods of time.

3 Adam and Rogers (1978)
The critical nuclide and pathway for low-specific-activity solids such as mill tailings and coal ash is the radon reclamation scenario (inhalation of radon by a reclaimer, e.g., by someone living in a house built on the site). The impact from this exposure event can be reduced by two orders of magnitude by burying the coal ash or tailings sufficiently deep to preclude exposures to unsuspecting reclaimers (about 10 m).

4 Adam and Rogers (1978)
Large-volume, low-specific-activity materials, specifically uranium mill tailings, were found to possibly require deeper burial than the typical 1 m of soil cover now envisioned, or removal of radium and thorium during milling to insure that potential intruders do not receive unacceptable exposures.

5 Macbeth et al. (1979)
Any unauthorized attempt to dig up the waste at an SLB site will be easily detected by inspection of the ground surface. Intrusion alarms and security fences are assumed to deter unauthorized attempts to get access to the wastes.

6 Macbeth et al. (1979)
Long-term hazards, after institutional controls are relinquished, [could arise for] construction on the former disposal site or [for] archeologists investigating an earlier civilization.

7 Macbeth et al. (1979)
It may be advantageous to render the waste unattractive to a potential reclaimer to enhance protection after institutional controls have been relinquished.

8 Macbeth et al. (1979)
IOB would provide significantly greater isolation and protection against inadvertent intrusion than SLB. For example, most reclamation activities would not involve excavation to the depth of the waste.

9 Macbeth et al. (1979)
Likelihood of future generations encountering the waste is less for IOB than for SLB, and hence public concern for moral and ethical questions should be reduced.

10 Healy (1980)
The intrusion pathway is probably the most controversial and provides some problems of interest. Some feel that it should not be included because we can place markers that will warn of the dangers and anyone penetrating in spite of this warning will be accepting the risk himself. On the other hand, providing markers that will withstand vandals and the ravages of time is difficult. In addition, if archaeologists or treasure hunters are as persistent in the future as they are now, old burial grounds will act as a magnet because of historical interest and the presence of valuable materials and items.

11 Healy (1980)
Limits for wastes disposed of in long-lasting containers should be lower, to control intruder doses, than for limits in which degradation and mixing with the soil can be expected. Note that the present regulatory trend of requiring containers as long-term barriers will accentuate the problem.

12 Deichman (1980)
Erosion and intrusion control barriers should use techniques (e.g., natural vegetation and/or natural materials barriers) that are resistant to water and wind erosion, effective in reducing infiltration of precipitation, stable over long periods of time, and obstructive to burrowing animals.

13 Deichman (1980)
Intermediate-depth burial (IOB) would position the waste farther from plant root systems and fauna than does shallow land burial (SLB) and reduce the potential for exposure by erosion and intrusion by humans. These advantages should be weighed against the increased cost, reduced distance between waste and the water table, and the alternative of placing more effective barriers in trench covers of conventional SLB trenches.

14 USHRC (1981a)
[The] two primary safety objectives [are]: prevention of migration of radionuclides, primarily through groundwater, and prevention of exposure to inadvertent intruders.

15 Murphy and Holter (1980)
Excavation will most likely occur where knowledge concerning the presence or location of buried wastes is lacking. However, knowledge of the presence of buried waste is not a guarantee that excavation will not be performed.

16 USNRC (1981b)
Three intrusion pathways were analyzed. The concentration limited scenarios analyzed in the following subsections include (1) excavation into disposed waste or construction of a house or building upon the disposal facility and (2) persons living on the disposal facility. The activity-limited scenario analyzed involves potential use of contaminated water from a well drilled onsite.

17 USNRC (1981b)
To calculate impacts (concentration limits for disposal) all investigators agreed that intrusion events take place some hundreds of years following waste disposal, after institutional controls cease. That is, for the first few hundred years following the waste disposal, the disposal facility is assumed to be under the control of a government agency which precludes inappropriate use of the disposal facility. Following this time, the institutional controls are assumed to become ineffective and the persons are assumed to be allowed to intrude into the disposed waste mass and carry out such typical activities as construction of houses or living on the facility. The most restrictive of the scenarios (the scenario leading to the highest exposures) is then used to determine limiting concentrations for disposal of waste by the methods investigated.

18 USNRC (1981b)
If, on the other hand, the stable wastes were segregated from the easily degradable wastes, then the potential for degradation of the stable waste would be greatly decreased. Even after several hundred years, the waste mass should still be clearly recognizable as something other than ordinary dirt. It is not credible to suppose that an individual would attempt to construct a house or grow crops in a location characterized by large stacked metal cylinders filled with concrete. For such cases, exposures would be confined to those received during discovery of the disposed waste. Upon discovery, it is reasonable to expect that the intruder would cease operations while the matter would be investigated. As discussed below under institutional controls (Section 4.3.8), all knowledge about a disposal facility should not be lost and information about the facility would be assessed in determining a proper course of action with respect to the inadvertent intruder. If the individual chose to ignore information about the facility, the event would no longer be considered inadvertent intrusion.

A.2.1.5 Plant Uptake

1 Lipton (1931)
Waste material leached into solution can migrate off-site through three principal pathways:
(1) return to the surface through seepage and subsequent surface migration, (2) plant uptake, and (3) transport through groundwater.

2 Lipton (1931)
Plants growing above buried waste may absorb significant quantities of radioactive material, e.g., Sr-90 uptake at Savannah River Laboratory backfilled trenches.

3 Adam and Rogers (1978)
Observations/radionuclide migration (as of 1978) at 6 commercial sites (Richland, WA, Beatty, NV, Sheffield, IL, Morehead, KY, Barnwell, SC, West Valley, NY) and 5 DOE sites (Hanford, WA, INEL, ID, Los Alamos, NM, Oak Ridge, TN, Savannah River, SC) revealed migration by water mechanisms (surface water or groundwater) at 6 sites and by uptake through deep rooted plants at one site. These observations suggest that, in the near term, the water pathway is the most important, plant uptake can be important, and the other near-term mechanisms that might lead to exposure of the public are less important.

4 Jacobs et al. (1980)
Vegetation, particularly deep rooted plants, growing on the surface of covered burial trenches have accumulated radionuclides and represent a pathway for translocation of radionuclides from the trenches to the uncontrolled environment in four of the eleven sites. Translocation of radionuclides by deep-rooted plants is considered to be a significant long-term transport mechanism for radioactivity at Hanford and specifically for plutonium at LASL.

5 Jacobs et al. (1980)
In evaluating erosion control measures, consideration should be given to their ability to remain stable over long periods of time and to provide protection against intrusion by deep-rooted plants and by small burrowing animals as well as their effectiveness in providing short-term erosion control.

6 Macbeth et al. (1979)
Food pathways, if enhanced by reclamation efforts bringing wastes up to plow and root levels, could lead to exposures of up to 625 mrem/yr.

7 Deichman (1980)
Intermediate-depth burial (IDB) would position the waste farther from plant root systems and fauna than does shallow land burial (SLB) and reduce the potential for exposure by erosion and intrusion by humans. These advantages should be weighed against the increased cost, reduced distance between waste and the water table, and the alternative of placing more effective barriers in trench covers of conventional SLB trenches.

8 Murphy and Holter (1980)
The biological action of root uptake of radionuclides from the buried waste and from waste in the topsoil may establish a link to humans via the ingestion of locally grown crops. Ecological pathways involving the movement of waste material by waterfowl, burrowing animals, blowing weeds, etc., are not considered in this study.

9 Murphy and Holter (1980)
Plant roots, in addition to uptake of radionuclides, are also instrumental in the mechanical breakdown of buried waste and overburden material. Most reports of biological interaction with waste have involved plants.

A.2.1.6 Burrowing Animals

- 1 Jacobs et al. (1980)
There is a potential for small animals to intrude into buried wastes and translocate radionuclides. At LASL elevated levels of tritium have been found in honeybees.
- 2 Jacobs et al. (1980)
In evaluating erosion control measures, consideration should be given to their ability to remain stable over long periods of time and to provide protection against intrusion by deep-rooted plants and by small burrowing animals as well as their effectiveness in providing short-term erosion control.
- 3 Deichman (1980)
Erosion and intrusion control barriers should use techniques (e.g., natural vegetation and/or natural materials barriers) that are resistant to water and wind erosion, effective in reducing infiltration of precipitation, stable over long periods of time, and obstructive to burrowing animals.
- 4 Deichman (1980)
Intermediate-depth burial (IDB) would position the waste farther from plant root systems and fauna than does shallow land burial (SLB) and reduce the potential for exposure by erosion and intrusion by humans. These advantages should be weighed against the increased cost, reduced distance between waste and the water table, and the alternative of placing more effective barriers in trench covers of conventional SLB trenches.
- 5 Murphy and Holter (1980)
A rock layer provides a barrier to digging and burrowing animals, in principal, but its effectiveness for all species of significance is not firmly established (e.g., prairie dogs).

A.2.1.7 Direct Radiation

- 1 USHRC (1980b)
Direct gamma exposure from tailings or waste should be reduced to background levels.
- 2 USEPA (1980d)
Techniques which control radon releases reasonably well and have lasting effectiveness will essentially control airborne particles and direct gamma radiation completely.

A.2.1.8 Catastrophic Events

- 1 USDOE (1981a)
The safety assessment portion [of the environmental and safety report] examines consequences of potential operational accidents, natural disasters, radionuclide migration, and severe climatic conditions.

- 2 Deichman (1979)
Effect of off-normal weather conditions on burial sites [is an important technical issue]. "Catastrophic" storms likely at burial sites in intervals of decades or centuries (as well as more frequent severe weather conditions) are to be taken into account.
- 3 Jacobs et al. (1980)
Over long time periods, say several millenia, even the solid matrix can move significantly because of erosion or tectonic events.

A.2.2 Health Effects (Primarily Radiological Consequences)

- 1 USEPA (1977b)
Should radon exhalation from low-level natural radioactivity disposal sites be controlled, and if so, how?
- 2 USEPA (1977b)
Natural background (radiation) levels are the appropriate lower limits below which cleanup (deactivation/decommissioning) of a waste disposal site would not be justified.
- 3 USEPA (1978)
A waste-disposal risk assessment should be as realistic as possible.
- 4 USEPA (1978)
A waste-disposal risk assessment should consider resultant (from releases) health effects and assumptions of the relation of radiation dose to health effects.
- 5 USEPA (1978)
An adequate risk assessment for radioactive wastes should estimate the potential health effects on humans for 1,000 years.
- 6 USEPA (1978)
Should rulemaking considerations consider theories other than the linear hypothesis?
- 7 USEPA (1978)
Should (rulemaking considerations) address human contamination such as excreta and body burdens of radioactive materials?
- 8 USDOE (1981c)
What exposure to radiation will the public and workers receive from routine operations at the disposal site?
- 9 USDOE (1981c)
What exposure to radiation will the public and workers receive at the disposal site?
- 10 USEPA (1981a)
We (EPA) believe that a linear, nonthreshold dose-effect relationship is a reasonable basis for deriving estimates of radiation risk to the general public and for establishing regulations.

- 11 Owner/operators of new landfill disposal facilities must assure prevention of adverse effects due to migration of waste constituents in the subsurface environment. USEPA (1981d)
- 12 Are there situations that may require exposure to doses higher than normally permitted and, in these cases, should special guidance be provided. USEPA (1981c)
- 13 What radiation guidance should apply to workers who do not use (are not otherwise exposed to) radiation sources, but who are exposed to radiation due to the activities of workers under the control of other employers? USEPA (1981c)
- 14 Should radiation guidance include numerical values for the "quality" and "modifying" factors used to convert dose to dose equivalent? USEPA (1981c)
- 15 What relationship should be maintained between permissible levels of risk to health from radiation exposure and other regulated hazards of disease or accidents? USEPA (1981c)
- 16 Should the concept of lowest feasible level of radiation be applied to exposure of workers? USEPA (1981c)
- 17 How should the radiation protection principles requiring (a) justification of any exposure, and (b) reduction of the dose from justified exposure to the lowest practicable or as low as is reasonably achievable level be applied to exposure of workers? Should the concept of lowest feasible level be applied to exposure of workers? USEPA (1981c)
- 18 On what basis should radiation guidance be expressed for exposure of more than one organ or portion of the body? USEPA (1981c)
- 19 What organs and parts of the body should have designated radiation limits? USEPA (1981c)
- 20 Does existing radiation guidance adequately cover situations that involve exposure of less than the whole body? USEPA (1981c)
- 21 Should the radiation guidance reflect or cover medical, accidental, and/or emergency exposures? USEPA (1981c)
- 22 On what time basis should radiation guides be expressed? USEPA (1981c)
- 23 Should the same radiation guides apply to all categories of workers? USEPA (1981c)
- 24 Are the radiation doses currently received by workers and the maximum doses permitted by existing guidance adequately low? USEPA (1981e)
- 25 Once the probable exposures to (disposed-) waste are estimated, what methodologies are appropriate to predict human health effects?

- 26 Disposal methods selected should match hazard of the waste. Levin (1980)
- 27 Public hazards should be analyzed in terms of integrated long-term dose commitment. Macbeth et al. (1978)
- 28 The waste classification scheme that is recommended is one that is based on total hazard. USDOE (1980c)
- 29 Some LLHs have such small levels of radioactivity that they pose no significant hazard to the public. It should be so designated in an appropriate classification category. Environmental release is recommended as a safe disposal option for these wastes. USDOE (1980c)
- 30 Acceptable levels should be established for the safe release of solids as well as liquids and gases into the environment. USDOE (1980c)
- 31 Radium contamination is a major health concern because radium decays to radon, which diffuses into the air and which decays to radioactive solid materials. USDOE (1980b)
- 32 Radiological criteria must be developed for use as guidelines to determine (1) the extent of decontamination required at each site, (2) whether a radiological problem exists, and (3) standards for unrestricted use. USDOE (1980b)
- 33 The ultimate program objective is to preclude any future radiological problems at formerly used sites from previous MEO/AEC activities. USDOE (1980b)
- 34 The basis of the [preliminary] cost estimates for remedial action assumes contamination would be reduced to 5 picocuries of radium-226 per gram of soil (as comparable levels for other radionuclides), which is in the range of 2 to 10 times natural background. USDOE (1980b)
- 35 LLRMH goals for site selection are to:
(1) Protect present and future generations from unacceptable levels of radiation from waste radionuclides.
(2) Allow access to required resources.
(3) Minimize responsibilities and costs of RM to future generations. Falconer et al. (1981)
- 36 Determination of the potential hazards from long-lived radionuclides [is a priority technical issue]. Deichman (1979)
- 37 Interim storage would increase both occupational exposure and population risk. USDOE (1981b)
- 38 Classification by radiological hazard would: increase costs of waste management disposal, increase occupational risk for generator employees but decrease public risk, require new regulations (except for transportation), and enhance incentives for interstate compacts and new site development. USDOE (1981b)

- 39 USDOE (1981b)
Classification by total hazard is deemed desirable by the states, which [should] enhance development of regional compact and disposal sites, and it should achieve greater protection of the public than any alternative classification scheme. However, costs of waste management and disposal would increase substantially, and regulation development and enforcement would significantly impact on regulatory agencies.
- 40 USDOE (1981b)
By observing how workers unload, unbolt, and dump waste containers into trenches, operators have been able to reduce [occupational] radiation doses by up to a factor of two in the past year or so.
- 41 USDOE (1981b)
Issuance of a single set of [packaging] regulations for both transportation and disposal [of LLW] would have little effect on public health and safety.
- 42 USDOE (1981b)
The increment in dose [to the general population due to allowed releases of solid LLW] would be very small—considerably smaller than variations in natural background radiation due to differences in altitude and geology in different parts of the country.
- 43 USDOE (1981b)
In its draft position paper, NRC has suggested that the public radiation dose must be less than 1 m rem/yr, [which] is an extremely low radiation exposure rate and is very much lower than the doses received by the population from natural background radiation.
- 44 USDOE (1981b)
Not enough is known at present about either the intrinsic toxicity of the various chemical constituents of LLW's or how they break down under different disposal conditions to quantify their hazard, which can be done for radioactive species.
- 45 USDOE (1981b)
The basic technical evaluation questions are:
1. Given a limit on doses that can be [allowed to be] delivered in occupational exposure or to the general public, to what extent can a disposal alternative satisfy this requirement with current technology?
2. If current technology is inappropriate, how feasible are the needed improvements?
3. How widely available are sites with the hydrogeologic characteristics needed for a given disposal technique?
- 46 USDOE (1981b)
SLB has been safely practiced for over 30 years at government sites and for nearly 20 years at commercial disposal sites, and in no instance has concentration of radionuclides even approached regulatory standards.
- 47 USDOE (1981b)
Chemical hazards of wastes in SLB can be due to constituents whose degradation can be enhanced by appropriate burial conditions, whose lifetime is essentially infinite, or which synergistically increase radiological hazards. EPA regulations require a 30 year post-closure control period for hazardous wastes.
- 48 Adam and Rogers (1978)
How does the population dose commitment for limiting scenarios (no-action and an ALARA alternative) for FUSRAP waste disposal compare with the population dose commitment from natural background (10 trillion person-rem) and the commitment from mill tailings if all known U.S. reserves were processed (30 million to 3 billion person-rem)?
- 49 Adam and Rogers (1978)
The most important mechanism by which individuals can be exposed to radioactivity from waste are: (1) Inhalation of dust by reclaimer digging in the waste, or by residents on the reclaimed site, (2) Ingestion of water from a well dug by reclaimer, (3) Consumption of food grown in a garden containing contaminated soil, (4) Direct exposure to workers or residents from gamma radiation, (5) Atmospheric transport to individuals via continuous releases and accidental releases, (6) Groundwater migration to a resource waterway, (7) Surface erosion to a resource waterway.
- 50 Adam and Rogers (1978)
As a radionuclide decays the decay daughters generated can also cause negative environmental impacts, the sum total of which can be larger than the maximum impact of the parent.
- 51 Adam and Rogers (1978)
The relative impact of the radionuclides in FUSRAP waste (see NUREG 0456) should be calculated as a function of time and used as a relative measure of the potential hazard of FUSRAP waste and the migration of this hazard by decay.
- 52 Adam and Rogers (1978)
The emission of radon gas is one of the more significant concerns associated with waste that contains U-238 (e.g., FUSRAP waste).
- 53 Adam and Rogers (1978)
The method of analysis used by Adam and Rogers (1978) for calculating exposure events by different dispersion pathways may be useful for analyzing the exposure events from FUSRAP waste at near-surface disposal sites.
- 54 Adam and Rogers (1978)
The concerns and issues associated with the disposal of coal ash might be used as a measure for gauging the seriousness of concerns and issues associated with the disposal of FUSRAP waste. The ratio of the coal-ash/mill tailings radon fluxes range from 0.001 to 0.1.
- 55 Adam and Rogers (1978)
The ratio of calculated/measured dose rates from evaporator plume releases for Sr-90 and Cs-137 are 5 and 1/5, respectively. The ratio of calculated/measured trench water concentrations from surface water transport for Sr-90 and Cs-137 are 4 and 10, respectively. These results suggest that calculated doses rates should be regarded as order-of-magnitude estimates, and that the estimates obtained by means of the analysis used in NUREG 0456 (Adam and Rogers (1978)) are not necessarily conservative, i.e., both over-estimates and underestimates can occur.
- 56 Adam and Rogers (1978)
The concept of truncating calculations of populations when individual exposures fall below some lower limit should be considered.
- 57 Adam and Rogers (1978)
Fifty-year dose commitments are appropriate for comparing population doses.
- 58 Macbeth et al. (1979)
Although in some cases containment of wastes has been less than initially expected, no large health hazards to members of the public have resulted from waste disposal operations.

- 59 Macbeth et al. (1979)
Short-term radiological effects include direct gamma exposure to workers and public along transportation routes, accidents causing airborne contamination, and small airborne release in normal operations. The pathways considered most important for comparative analysis are direct exposure to ionizing radiation from waste packages, extremely small ongoing release from contaminated package surfaces, and airborne contamination from accidents or spills.
- 60 Macbeth et al. (1979)
Exposures associated with transportation of LLH are based on 1.8×10^{-5} manrem/car mile developed in WASH-1238.
- 61 Macbeth et al. (1979)
Because the operation personnel [at an SLBF] are trained radiation workers aware of the hazards involved, they will protect themselves and keep to ALARA standards.
- 62 Macbeth et al. (1979)
Construction workers digging into wastes at a typical SLBF site 150 years after burial could receive by dust inhalation doses of 110 mrem. (see Macbeth 1979 Table 3.3)
- 63 Macbeth et al. (1979)
Food pathways, if enhanced by reclamation efforts bringing wastes up to plow and root levels, could lead to exposures of up to 625 mrem/yr.
- 64 Macbeth et al. (1979)
Among the expected radiological impacts of a "reference" SLBF, food pathways yield the most significant long-term effects, while accidental airborne releases lead to the largest short-term effects (see Macbeth 1979, Table 3.6).
- 65 Macbeth et al. (1979)
Engineering improvements to historic SLB should make no significant change in overall non-radiological health impacts, but about a 15% reduction in radiological health impacts. (Macbeth 1979, Tables 3.8 and 3.9)
- 66 Macbeth et al. (1979)
Radiological impacts for IOB, as estimated, would be less than for SLB by a factor of 5 to 6. Percolation of surface water down to the waste is retarded, and inhalation and food pathway exposure virtually eliminated.
- 67 Macbeth et al. (1979)
As compared to present SLB practice, doses due to waste handling accidents might be reduced by, say, 25% by use of air supported weather protection buildings since many of the waste handling operations take place within the dispersion barrier they provide.
- 68 Macbeth et al. (1979)
Accident dose rates might be reduced from those for current SLB practice by a factor of two for SDF disposal, since at least half the waste handling occurs inside the containment provided by the structure.
- 69 Macbeth et al. (1979)
Actual values [of doses via consumption of contaminated water] are extremely site and waste form dependent and should be determined on a case by case basis [for] a predictive application of the methodology.
- 70 Macbeth et al. (1979)
[For a typical inventory of LLH], the only nuclide of significance for a direct gamma radiation after 150 years is Cs-137.
- 71 USNRC (1980b)
Direct gamma exposure from tailings or waste should be reduced to background levels.
- 72 Healy (1980)
The proper approach is to use current Federal Radiation Council (FRC) guidance, signed by the President, as a basis. This guidance calls for a maximum whole body dose to an individual of 0.5 rem/yr or 0.17 rem/yr to a critical group in the population. For simplicity, one may use 0.5 rem/yr to any organ of the individual who is likely to be the highest exposed. This limit can then be applied to the year for which the maximum dose is received - 70 years in the case of long-lived, well-retained nuclides.
- 73 USNRC (1980a)
With respect to overall impacts, the most important mill-released radionuclide is Rn-222, which is released in gaseous form and transported long distances, exposing large populations albeit at extremely small levels above background. Total exposure estimates, which include radon and daughters, indicate that radon is the single greatest contributor to risk.
- 74 USNRC (1980a)
The proposed limit on radon flux of 2 pCi/m²/sec provides for a radon exhalation rate that will be within the observed range of variability of natural flux rates. Beyond this, the proposed limit was selected in consideration of several additional factors, no single one of which by itself, leads conclusively to the proposed level of control, but which taken together support the requirements as being reasonable ones. The factors considered include risk to individuals, population exposures, total costs and long-term physical isolation and stability.
- 75 USNRC (1981a)
NRC is applying a 500 mrem/yr maximum individual exposure limit for the unusual case of inadvertent intrusion (which may never occur), based on ICRP recommendations.
- 76 USNRC (1981a)
NRC does not anticipate that EPA standard for release of radioactivity to the environment from disposal facilities, when promulgated, will be much higher than that for release to the environment from fuel cycle facilities (25 mrem/yr whole body exposure; 40CFR190) or any lower than that for radioactivity in drinking water (4 mrem/yr whole-body exposure, 40CFR141).
- 77 USNRC (1981a)
NRC has selected an objective which requires that any movement of radioactivity not result in calculated doses exceeding 25 mrem/yr to an individual standing at the site boundary or exceeding the EPA Drinking Water Standards at the nearest public drinking water supply.
- 78 USNRC (1981a)
Any waste which, after the 100 year period of institutional control, would cause exposure greater than 500 mrem to an inadvertent intruder is identified as class C intruder waste and must be protected by deeper burial (a minimum of 5 meters below grade) or an equivalent natural or engineering barrier.
- 79 USNRC (1981a)
NRC has not developed a classification of waste, based on the total hazard. The classification is based on radiation protection considerations. Other hazards presented by associated components of waste (e.g., chemical and biological hazards) are addressed by exclusion or treatment of certain chemical, physical, and biological forms of waste.
- 80 USNRC (1981a)
[The] two primary safety objectives [are]: prevention of migration of radionuclides, primarily through groundwater, and prevention of exposure to inadvertent intruders.

- 81 Institutional control periods of up to 100 years permit the disposal of Class A segregated and Class B stable waste without special provisions for intrusion protection, since these wastes will decay during the 100 year period to levels that do not pose a danger to public health and safety. USHRC (1981a)
- 82 Class C waste must be buried deeper than other waste, or, if site conditions prevent this, protected by engineering barriers. The assumed effective life of these barriers is 500 years, and the maximum radionuclide concentration for all wastes must, in general, be such that at the end of the 500 year period no danger to public health and safety remains. USHRC (1981a)
- 83 Analysis [in license applications] of protection of individuals during operation must assess expected exposures due to routine operations and likely accidents during handling, storage, and disposal of waste. USHRC (1981a)
- 84 Radioactive releases to the general environment in ground water, surface water, air, soil, plants, or animals must not result in an annual dose exceeding an equivalent of 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of any member of the public. USHRC (1981a)
- 85 The public exposure limits proposed by the NRC are given as annual maximum doses, whereas a common view is that the hazard of an activity should be measured by the total dose commitment attributable to that activity. USHRC (1981a)
- 86 Concentrations of radioactive materials in groundwater must not exceed the maximum containment levels established in the National Primary Drinking Water Standards at the nearest public drinking water supply (a limit of 10 pCi/l above background must be used for uranium and thorium). USHRC (1981a)
- 87 Gamma radiation at the surface of covers must be limited to within a few percent of the natural background levels of the site. USHRC (1981a)
- 88 There are no well established models for treating overland flow. Murphy and Holter (1980)
- 89 The calculated maximum annual doses are based on the ICRP Publication 2 and the ICRP Publication 10A metabolic models, the ICRP Task Group Lung Model, and standard man parameters values. To the best of our knowledge, there are no reported assessments of the accuracy of dose calculations using these models and parameter values. Dose results are presented with no indication of the error associated with their use. Present insights into the degree of uncertainty involved are very limited and qualitative. Murphy and Holter (1980)
- 90 To determine release conditions for a decommissioned LLW burial ground this study uses the concept of the maximum annual dose to an organ of reference of a maximum-exposed individual. The maximum-exposed individual is assumed to live and work on the decommissioned site, to eat all of his food from crops and animal products grown on the site, and to drink water from a well drilled on the site. Murphy and Holter (1980)
- 91 Inhalation doses to decommissioning workers are expected to be negligible for site stabilization and long-term care, since these operations do not normally involve direct contact with buried waste or contaminated soil. However, waste relocation operations may involve the generation of dust containing radioactive particulates, and these operations could result in substantial inhalation doses. The use of respiratory equipment to minimize inhalation doses from those operations which have potential for the generation of airborne radioactivity, is assumed. Murphy and Holter (1980)
- 92 External sources of exposure include cosmic rays, together with the radionuclides they produce, and the primordial radionuclides in the earth. Internal exposure from natural radionuclides inhaled or ingested via foods and drinking water suggest that external exposure appreciably (e.g., potassium-40 adds 17 mrem.) Large segments of the population in the United States receive natural external radiation doses varying from 41 to 105 mrem per year simply because of geographic location. Variations in natural exposure to thorium in monazite sands along the southeastern coast of India range from 130 mrem to 2,800 mrem; while on the coast of Brazil, exposure ranges from 90 to 2,800 mrem with an average of 550 mrem per year. There is no scientifically established evidence, despite contrived attempts to prove it, that there are basic harms to those so exposed. Maxey (1979)
- 93 Most population dose calculation procedures, including those in Reg. Guide 1.109 and NASH-1400, are consumption oriented in the sense that population doses for the ingestion pathway are calculated as the product of (1) the number of people in the local area, (2) the per-capita ingestion of food stuffs, (3) the concentration of radionuclides in locally grown foods, and (4) appropriate ingestion dose factors. This approach yields incorrect population doses when contaminated foods are exported and eaten elsewhere and when the consumption of uncontaminated foods is not considered. A simpler and more consistently correct approach to the calculation of total population ingestion dose is the production oriented model used here. In this model, the population dose for the ingestion pathway is the product of (1) the quantity of food produced locally (and thus contaminated), (2) the concentration of radioisotopes in this food, and (3) the appropriate dose factors. In the production model approach, it is assumed that all foods grown are consumed by humans. The correct population ingestion is thus calculated regardless of local population, per capita consumption, or food export/import situations. Lester et al. (1981)
- 94 The shallow-land burial (SLB) Systems Model is being developed to provide a means of evaluating licensing alternatives in terms of site and operational parameters. The objective is to provide user-oriented code which makes efficient use of available data to perform dose assessment of various assumed scenarios. The SLB Model is designed from existing models and codes so that it is composed of previous established methodologies. The SLB Systems Model is not intended to be a risk model in the sense that all possibilities are considered and the most rigorous calculation made. The SLB Model is rather directed toward making comparisons of situations to weigh alternatives. A set of scenarios is being provided with the SLB Model. Lester et al. (1981)

A.3 THE NATURAL ENVIRONMENT

- 1 Development of standard methods for measuring distribution of radionuclides in soil [is desirable]. Levin (1950)
- 2 The site selection process should include sufficient detailed information on site geology, hydrology, and meteorology to identify and evaluate all potential migration pathways. Lipton (1981)
- 3 Development of techniques to characterize and improve sites for optimizing burial ground performance [is a priority technical issue]. [Involves] comparative studies of radionuclide movement from sites having a range of climatic, edaphic, geologic, and hydrologic conditions. Balance among complementary site characteristics, including alterations to improve performance. Deichman (1979)
- 4 [There is] an interminable list of "what if" questions: What if the weather pattern changed leading to greatly increased or decreased rainfall? What if drainage patterns were changed by earthquakes? What if a new ice age moved about large quantities of soil? What if the site were forgotten and used to grow who knows what crops? Cohen and Jow (1978)
- 5 Ideally, precipitation at the site should be low, distances to aquifers should be long, aquifer flows and utilization should be low, and underlying strata should be neither highly fractured nor contain voids or flow channels. Macbeth et al. (1979)
- 6 In selecting among alternative tailings disposal sites or judging the adequacy of existing sites, the extent to which a program meets the broad [NRC] objectives depends on:
 - . Remoteness from populated areas.
 - . Immobilization and isolation of contaminants from usable groundwater sources, [as provided by] hydrologic and other natural conditions.
 - . Potential to minimizing erosion, disturbance.
 - . Dispersion by natural forces over the long term.USNRC (1980b)
- 7 In support of a tailings disposal system proposal, the applicant/operator shall supply information concerning the following: (1) The chemical and radioactive characteristics of the solutions. (2) The characteristics of the underlying soil and geologic formations, particularly as they will control transport of contaminants and solutions. This shall include detailed information concerning extent, thickness, uniformity, shape, and orientation of underlying strata. Hydraulic conductivity of the various formations shall be determined. (This information shall be gathered by borings and field survey methods taken within the proposed impoundment area and in surrounding areas where contaminants might migrate to usable groundwater. The information gathered on boreholes shall include both USNRC (1980a)

geologic and geophysical logs in sufficient number and degree of sophistication to allow determining significant discontinuities, fractures, and channeled deposits of high hydraulic conductivity. If field survey methods are used, they should be in addition to and calibrated with borehole logging. Hydrologic parameters such as permeability shall not be determined on the basis of laboratory analysis of samples alone; a sufficient amount of field testing (e.g., pump tests) shall be conducted to assure actual field properties are adequately understood. Testing shall be conducted to allow estimating chemisorption/attenuation properties of underlying soil and rock.) (3) Location extent, quality, capacity and current uses of any groundwater at and near the site. Furthermore, steps shall be taken during stockpiling of ore to minimize penetration of radionuclides into underlying soils; suitable methods include lining and/or compaction of ore storage areas.

- 8 Analysis [in license applications] of long-term stability and of need for postclosure maintenance must rest on analysis of active natural processes such as erosion-mass wasting, slope failure, and adjacent soils, and surface drainage. USNRC (1981a)
- 9 [Closure application must include] any additional disposal site data obtained during operational period (geologic, hydrologic, etc.) which is pertinent to long-term containment USNRC (1981a)
- 10 Program objectives for environmental surveillance and records maintenance include:
 - . detection of changes in and evaluation of long-term trends of concentrations of radionuclides in the environment, with the intent to detect radionuclide migration and initiate appropriate actions
 - . collection of data on the history of contaminants released to the environment, with the intent of discovering previously unconsidered pathways and modes of exposure.Murphy and Holter (1980)
- 11 The availability of data is a large concern. Many existing models for exceed data availability and their complexity is wasted since many features are not used. Models used in this study were chosen to maximize use of available data and avoid features which could not be used at present or in the foreseeable future because of lack of data. Lester et al. (1981)

A.3.1 Hydrology

- 1 For hazardous waste disposal siting, is it physical and chemical characteristics as well as quantities and reasonable to consider the "500-year flood" as the flood of concern in siting standards? USEPA (1981a)
- 2 In waste disposal siting standards, should (1) facilities be prohibited within floodplains or (2) facilities be allowed within floodplains if the facility is "properly built?" USEPA (1981a)
- 3 Is it appropriate to allow a waste disposal facility on a floodplain only if it is shown that no inundation would occur? USEPA (1981a)

4	Should "Flood of Concern" Assessment depend on the degree of hazard imposed by (1) type of hazardous waste buried, and (2) quantity of disposed hazardous waste?	USEPA (1981a)	17	Groundwater monitoring-procedure design must consider evaluation procedures, including methods for determining extent and rate of waste-constituent migration.	USEPA (1981d)
5	It may be difficult to acquire maps identifying "500-year floodplains," and data on floods covering a 500-year period.	USEPA (1981a)	18	Future siting of new LLW disposal facilities should give greater attention to the hydrologic characteristics of proposed locations than has been the case in the past.	USDOE (1979)
6	There is concern that floodplain standards would force closure of existing waste disposal facilities.	USEPA (1981a)	19	Monitoring of low level waste burial sites for only decades might be insufficient.	USDOE (1979)
7	What effects on surface and ground waters will disposal operations cause?	USDOE (1981c)	20	The recommendation that "Future siting of LLW disposal facilities should give greater attention to hydrologic characteristics" fails to recognize extensive hydrologic investigation of present sites prior to licensing.	USDOE (1979)
8	In hazardous-waste management, consideration should be given to degradation of water quality and background concentrations of discharged (migrating) substances in water and sediments.	USEPA (1980b)	21	With what degree of confidence can we predict the direction and velocity of groundwater flow (under disposal site) prior to contamination of the groundwater by the leachate plume?	USEPA (1981e)
9	Technical requirements should prevent water run-on to the disposal facility.	USEPA (1980c)	22	If one ignores all attenuation, how well can one predict the transport of (buried-waste) leachate constituents (to groundwater)?	USEPA (1981e)
10	Technical requirements should control water run-off from the disposal facility.	USEPA (1980c)	23	How well can one predict the degree of which the (waste-) leachate plume will expand, and concentrations of (migrating) constituents will decrease by virtue of molecular diffusion?	USEPA (1981e)
11	Disposal site owner/operator should provide a description of the earth materials in the saturated zone in which the leachate released from the land disposal facility will migrate.	USEPA (1980c)	24	How well can we predict the degree to which (migrating waste) constituents concentrations will decrease by virtue of mixing with the groundwater?	USEPA (1981e)
12	Disposal site owner/operator should provide a description of the hydrogeology of the area surrounding the facility.	USEPA (1980c)	25	To what extent can mitigating mechanisms be expected to cause the decay of (migrating waste) constituent in the saturated (groundwater) zone?	USEPA (1981e)
13	Disposal site owner/operator should provide a description of the discharges (into surface water) and withdrawals of groundwater that will be mixed with leachate from the disposal facility	USEPA (1980c)	26	Where knowledge of (buried-waste) leachate quality entering the groundwater is highly uncertain, what simplified approaches can be used to characterize plume migration?	USEPA (1981e)
14	Disposal site owner/operator should provide a description of the use of all surface water and groundwater that comes in contact with the projected leachate plume from disposed wastes.	USEPA (1980c)	27	Is it possible to predict the concentration of (migrating waste) constituents in the groundwater even within several orders of magnitude?	USEPA (1981e)
15	Owner/operators of new landfill disposal facilities must assure prevention of adverse effects on ground water quality.	USEPA (1981d)	28	What assumptions can one make about future groundwater and surface-water use and of land-use patterns in order to predict future exposures (to disposed waste)?	USEPA (1981e)
16	Owner/operators of new landfill disposal facilities must assure prevention of adverse effects on surface water quality.	USEPA (1981d)	29	[In] commercial site selection, the final decision [is] based on hydrogeological and economic factors.	Macbeth et al. (1978)
			30	Solid waste is usually buried in the shallow surface soil to subsurface geology transition zone. [Since] this zone has not received much geologic study, [there are] uncertainties as to subsurface hydrology.	Macbeth et al. (1978)

- 31 The single most important factor affecting containment is the degree to which groundwater can contact the waste and cause migration of radionuclides. Macbeth et al. (1978)
- 32 Potential problems associated with SLB include possible land reclamation, groundwater leaching and transport, and surface erosion. Macbeth et al. (1978)
- 33 Deeper land burial LB, with final cover of 10 to 20 m of clean soil, would largely avoid certain shallow land burial problems: inadvertent encounter with waste, water infiltration, erosion to expose waste before it decays to innocuous residual activity. Macbeth et al. (1978)
- 34 Although undisturbed soil may have low permeability, excavated soil [if] used to backfill trenches may have high permeability. The "bathtub effect" can result. Lipton (1981)
- 35 Waste material leached into solution can migrate off-site through three principal pathways: (1) return to the surface through seepage and subsequent surface migration, (2) plant uptake, and (3) transport through groundwater. Lipton (1981)
- 36 Migration through groundwater must be considered [if] waste containers are designed for safety only during transportation and burial. Lipton (1981)
- 37 Retention [of radionuclides] by soil is commonly indexed by the distribution coefficient [Kd], which can be tested in a laboratory but without certainty that the laboratory measurement will be valid under field conditions. Lipton (1981)
- 38 It is expected that tritium, ruthenium-106, and possibly technetium-99 will be the critical radionuclides for groundwater or surface water migration, but any radionuclide present in a trench should be considered capable of migration. Lipton (1981)
- 39 Organic complexes, such as chelating agents, often form highly mobile complexes with normally well-retained radionuclides. Lipton (1981)
- 40 The effectiveness of a monitoring system largely depends on the knowledge of a site's geology and hydrology, (e.g., so) that sampling points are properly placed in relation to possible paths of migration. [DAN, 1976] Lipton (1981)
- 41 A Dames and Moore report emphasizes the use of hydrogeological modeling to determine cost-effective placement of monitoring wells. Lipton (1981)
- 42 The USGS has published a list of 17 characteristics of a proposed site which should be determined to decide if it is satisfactory. These include: (1) Depth to water table, including perched water tables if present. (2) Distance to nearest points of ground, spring, or surface water usage (includes well and spring inventory). Lipton (1981)
- (3) Ratio of pan evaporation to precipitation minus runoff (by month for at least two years).
- (4) Water table contour map.
- (5) Magnitude of annual water table fluctuation.
- (6) Stratigraphy and structure to base of shallowest confined aquifer.
- (7) Baseflow data on perennial streams traversing or adjacent to site.
- (8) Chemistry of water in aquifers and aquitards and of leachate from trenches.
- 43 The site shall be located in an area not subject to flooding. This criterion excludes floodplains, coastal areas prone to hurricanes or storm surges, and regulatory floodways. [Also] marshes, swamps, bogs, mudflats, and areas with small enough slopes that precipitation and snowmelt can pond. Falconer et al. (1981)
- 44 The site shall be located in areas where hydrogeologic conditions allow reliable performance prediction. Complex flow systems, such as in cavernous fractured materials, may not be suitable. Falconer et al. (1981)
- 45 The site shall allow waste to be buried either completely above or below the transition between the unsaturated zones. For burial in the saturated zone, preferable earth materials are fine grained with low hydraulic conductivity such that molecular diffusion is the dominant solute migration mechanism. Falconer et al. (1981)
- 46 Characteristics of earth materials and groundwater chemistry at the site shall favor retention of radionuclides and other contaminants. The rate of subsurface migration depends primarily on the mineralogy and surface area of geologic material, groundwater chemistry, and groundwater flow rate. Falconer et al. (1981)
- 47 Preliminary site screening is to determine whether a state or region can site a facility at all. Finding a suitable site in an area is less likely if it contains one or more of the following: wetlands, shallow groundwater tables, high precipitation and low runoff, flood plains, large population, or valuable lands. USDOE (1981a)
- 48 Evaluation of the technical feasibility of Intermediate Depth Burial [is a priority technical issue]. In comparison to SLB, for example, there is increased isolation of waste, greater operational costs, decreased distance to water table. Deichman (1979)
- 49 Determination of mechanisms controlling water/radionuclide transport in unsaturated zones [is a priority technical issue]. Deichman (1979)
- 50 Determination of sorptive capacities for radionuclides in soil/solution systems [is a priority technical issue]. Deichman (1979)
- 51 Sorptive coefficients should be determined using soil materials and groundwater as they exist at the site. Deichman (1979)
- 52 Detailed study of sorption mechanisms is particularly important for the more hazardous and long-lived radionuclides, to predict their retardation in geologic formations. Deichman (1979)

- 53 USDOE (1981b)
Water management difficulties could pose a long-term operational problem for the closed Harey Flats site.
- 54 USDOE (1981b)
Because disposal operation have modified the hydrogeological characteristics of the Hest Valley site, erosion control and water management could pose major long-term problems.
- 55 USDOE (1981b)
MRC feels that the main effort [connected to leachability] should be put into minimizing water access to the trench in the first place.
- 56 USDOE (1981b)
The basic technical evaluation questions are:
1. Given a limit on doses that can be [allowed to be] delivered in occupational exposure or to the general public, to what extent can a disposal alternative satisfy this requirement with current technology?
2. If current technology is inappropriate, how feasible are the needed improvements?
3. How widely available are sites with the hydrogeologic characteristics needed for a given disposal technique?
- 57 Jacobs et al. (1980)
The most serious technical problems in shallow land burial are related to water management. Water provides a primary vehicle both for erosional processes, which can reduce the structural integrity of waste trenches and the trench caps and for migration of the radionuclides. Radionuclide migration in water and subsequent possible exposure to the public, begins with entry of water into the burial trench. The most common ways water comes into contact with the waste are from infiltration of precipitation through the trench caps and/or walls or from erosion leading to exposure of the buried waste.
- 58 Jacobs et al. (1980)
Water has come into contact with waste in burial trenches at six of the eleven major land burial facilities. (Solutions for some of these water problems have been implemented or proposed.)
- 59 Jacobs et al. (1980)
Proximity of trenches to groundwater and surface water is a problem in humid regions, particularly in areas where the permeability of surface formations is low, where the ground water lies at a short distance below the surface and the stream density is high, at the OPML site, where the precipitation is highest of all the burial sites, the only significant barrier to radionuclide migration is the adsorptive property of the soil.
- 60 Jacobs et al. (1980)
After wastes have been placed in trenches, the geologic formation is considered the primary barrier to radionuclide migration. Water is the principal vehicle for radionuclide transport; thus knowledge of the direction, depth of water table, flow paths, rate of movement, and dispersion of water coupled with the mechanisms and degree of interactions of specific radionuclides with the formation are required to understand radionuclide migration.

- 61 Jacobs et al. (1980)
Ion exchange is one of the major interaction of radionuclides with the geologic formation. However, the presence of fissures in the geologic unit may short circuit opportunities for ion exchange of radionuclides mobilized during leaching by infiltrating water. Mechanisms of interaction other than ion exchange may predominate and they are not always well understood. Chemical precipitation and filtration, mineral replacement, surface exchange reactions, and physical adsorption are other important interactions which have been studied. In some cases even the physical characteristics and the direction of the pathway is not clearly defined.
- 62 Jacobs et al. (1980)
The hydrogeologic data available at most sites are insufficient to permit the design of an adequate monitoring program. Examples of the kinds of geohydrologic data which have been specifically noted as lacking at one or more of 8 of the 11 major LLW burial sites are as follows:
(1) rate of infiltration; (2) soil permeability;
(3) permeability in fissured deposits, and stringers, and coal seams; (4) depth to the water table; (5) direction and rate of groundwater movement; (6) porosity;
(7) distribution coefficients for specific radionuclides under field conditions; (8) leachability of radionuclides from waste; (9) extent and orientation of fractures;
(10) sorption characteristics; (11) hydrodynamic dispersion properties; (12) degree of anisotropy of the glacial till; (13) secondary permeability; (14) water balance;
(15) Saturated zone thickness; (16) hydraulic conductivity of different layers; (17) presence and extent of solution channels; and (18) Detailed lithology and character of alluvial deposits.
- 63 Jacobs et al. (1980)
The major vehicle for transport of radionuclides in the ground is convective movement of groundwater. When water is the transporting vehicle, one must have knowledge of the direction, flow path, rate of movement, and dispersion as well as the mechanism and degree of interactions of specific radionuclides with the information in order to predict radionuclide migration. In absence of moving groundwater the rates of movement of nongaseous radionuclides by molecular or ionic diffusion are very small.
- 64 Jacobs et al. (1980)
An important technical issue is the facilitation of measurements and compilations of geohydrologic information needed to develop predictive capabilities for radionuclide migration and for the design of environmental monitoring programs for performance evaluation. At most sites where shallow land burial of radioactive waste is conducted, at least part of the geohydrologic information needed to provide a suitable basis for predicting radionuclide migration is lacking. Most of the major contractor facilities have ongoing programs for field studies of groundwater movement. Less effort has been devoted, until recently, to measuring site-specific hydrodynamic dispersion characteristics although the importance of such information has been recognized for some time.

- 65 Conditions, factors and properties that are important for predicting the hydrogeological dispersion of radionuclides through the ground include: the selectivity factor, the exchange capacity, the concentrations of competing cations, the crystal structure of the mineral and nature of the exchanger surface, the pH of the system and buffer properties of the soil, oxidation-reduction conditions, physical adsorption characteristics, the occurrence of organic or inorganic ligands that might lead to the formation of stable complexes which are less subject to chemical or physical adsorption, and biological activity that can lead to the formation of stable complexes. Jacobs et al. (1980)
- 66 After wastes have been emplaced in trenches, the geologic formation is considered to be the primary barrier to radionuclide formation. Water is the principal vehicle for radionuclide transport, and most efforts in developing predictive models for radionuclide movement from burial grounds have involved modeling of groundwater and solute movement. Most models have been based on ideal behavior of ion exchange in groundwater flow systems which can be described in simple mathematical terms. Less attention has been given to vapor transport and other mechanisms of radionuclide translocation. Jacobs et al. (1980)
- 67 Specific items related to water management that need additional research and development emphasis include: (1) field testing and engineering evaluation of techniques for control of infiltration and erosion; and (2) development of a rationale for arriving at a balance between control of infiltration and erosion. Jacobs et al. (1980)
- 68 More accurate modeling of effects of unsaturated flow conditions, percolation, evapotranspiration, and geometric distributions of waste within the disposal site may be needed. Macbeth et al. (1979)
- 69 In Europe, burial in coarse sand has been successful by placing a layer of fine sand over the coarse trench bottom. Water penetrating the waste and fine sand is held up at the coarse-fine interface because of the stronger capillary attraction in the fine sand. This is effective only where the ground is not saturated. Macbeth et al. (1979)
- 70 Two groundwater pathways involving leaching and migration from the waste (at an SLBF) have been analyzed: drinking from a well adjacent to the site, and drinking from a nearby stream supplied by an aquifer underlying the site. (See Macbeth 1979, Table 3.4) Macbeth et al. (1979)
- 71 Improvements in burial trench design could include:
 . Inclined trench bottom plus sump to avoid "bathtub effect".
 . Compacted clayey or silty soil under trench bottom, for enhanced ion exchange.
 . Coarse sand layer between waste and trench bottom, to ensure that water drains away from the waste.
 . Drainage ditches, filled with crushed rock along bottom of each trench wall.
 . Sump or drain at lower end of trench, with means of sampling and pumping accumulated water.
 . Process all water entering sump or drain, e.g. via an ion exchange column. Macbeth et al. (1979)
- 72 Upstream rain catchment areas must be minimized to decrease erosion potential and the size of the maximum possible flood. USHRC (1980b)
- 73 Hydrologic parameters such as permeability shall not be determined on the basis of laboratory analysis of samples alone; a sufficient amount of field testing shall be conducted to assure [that] actual field properties are understood. USHRC (1980b)
- 74 The major release mechanisms (and pathways) to man that can occur over time are as follows: erosion and transport to streams (drinking, uptake in fish, irrigation); leaching to aquifer (drinking, irrigation); aquifer to stream (drinking irrigation, fish); intrusion (resuspension); exposure of wastes (resuspension, ingestion in foods). Additional release mechanisms exist, but analysis indicates that, when carried to an extreme, conditions approaching those noted above will be present. Healy (1980)
- 75 If releases to a stream are in the form of particulates from direct erosion to the stream, or if the radionuclides are rapidly adsorbed on the sediments if released in ionic form, the problem is contamination of sediments and the movement of these sediments rather than dilution in the water flow of the stream and a transitory passage for each release time. The possible increase in concentrations in bottom sediments at low-flow regions, such as dams or estuaries where fresh water meets the salt water, is then of particular concern. Healy (1980)
- 76 If deeper burial, perhaps in a mined cavity at depths of 10 - 100 meters, were utilized, so that intrusion or erosion or other methods of exposure to wastes is essentially impossible, leaching to the groundwater becomes the controlling factor, and the limiting radionuclide concentrations (for a given exposure limit) could be at least one order of magnitude greater. Such a move would allow the surface to be used by people and, if well-designed, could eliminate much of the technical objection to burial grounds. Healy (1980)
- 77 Near-surface media (e.g., soils) are invariably non-isothermal, nonisotropic, and nonhomogeneous, so that material transport is rarely simple. In partially saturated geohydrologic systems, radionuclide species are typically dissolved in the vapor or solid phase, depending on the burial conditions and the chemical species of the radionuclides. The relative distribution among these phases may change in both time and space. Radionuclides can migrate in either liquid, gas, or solid form. The mechanisms causing migration under complex environmental conditions experienced at burial are not completely understood. Deichman (1980)
- 78 Many organic chemicals are complexing agents which can affect the leachability, solubility, and movement of radionuclides and toxic heavy metals. Inorganic complexes may also be formed and play an important role under appropriate chemical conditions. Knowledge of the types and quantities of complexing agents present, the radionuclide complexes present in trench leachates and within geologic formations, and the mechanisms and extent of interaction of these complexes with the media are needed in order to predict and compare the transport of radionuclides through the ground. Deichman (1980)

- 79 Soil microorganisms are known to solubilize various chemical elements in the soil by production of organic and mineral acids and other byproducts which may form complexes with radionuclides or may alter the chemical conditions of the solution, such as pH, which affect solubility. Soil microorganisms are also capable of transforming organic wastes into gaseous products. Conversely, microorganisms may degrade organic material, reducing organo-radionuclide complexation and enhancing the retardation of the radionuclides. Chemical and physical changes mediated by soil microorganisms may influence the bioavailability of radionuclides. Deichman (1980)
- 80 Hydrogeological criteria for the evaluation of the suitability of a site for shallow ground disposal that are general enough to cover most conceivable disposal environments are: (a) The land surface should be devoid of surface water and generally be stable with respect to its geomorphology. The site should not be subject to flooding, as would be a site placed on a flood plain encompassing potentially wet terrain. (b) The repository should be separated from fractured bedrock by a layer of geological materials sufficiently thick to retard the migration of radionuclides into the fractured zone. The subsurface pathways (groundwater flow) should not readily lead to public waterways or potentially usable aquifers, or to highly permeable areas of fractured rocks. (c) The predicted residence time of radionuclides within the groundwater flow system must be long enough for sufficient decay to occur before the radioactive waste constituents enter the human environment. The hydrogeological conditions must be simple enough for reliable residence time predictions to be made. (d) The natural water table, at its highest level, should be below the repository by at least a few meters and the hydrogeological setting should be such that large water-table fluctuations are unlikely. IAEA (1981)
- 81 The important hydrogeological considerations deal with the availability, location and movement of water; the properties of the disposal medium and underlying strata; and processes that could disrupt the site, introduce water to the waste, expose the waste, or otherwise return the waste to the environment and man. The identification of topics and factors that require consideration may be grouped according to successive stages of an investigation that proceeds through three successive stages of detail: (1) map/literature review; (2) field reconnaissance; and (3) detailed site analysis. IAEA (1981)
- 82 The topics that should be considered in a map/literature review of hydrogeological considerations for a site selection include: geology, topography, precipitation, evapotranspiration, nearest surface water, and nearest water use or discharge point. IAEA (1981)
- 83 The topics that should be considered in a preliminary field reconnaissance of the hydrogeological characteristics of a candidate site include: type of disposal media, prevailing wind direction, relief, subsidence, slope stability, flooding potential, erosion potential, depth to water table and depth to fractured bedrock. IAEA (1981)
- 84 The topics that should be considered in a intermediate field reconnaissance of the hydrogeological characteristics of a candidate site include: existing geological faults, disposal media, sorption capacity, thickness, engineering properties, permeability, effective porosity, structure, hydraulic gradients, hydrological budget, hydrological complexity, adequate water supply, monitorability and remediability. IAEA (1981)
- 85 The topics that should be considered in a detailed site analysis of the hydrogeological characteristics of a candidate site include: three-dimensional head distribution, disposal media and underlying site geology, including nearest confined aquifer, water chemistry, stratigraphy, ion exchange capacity, moisture content of unsaturated zone, soil moisture tension, transmissibility, natural fluctuation of water table, flow data for nearest streams including underflow, water table contour map, and possible measures for groundwater manipulation. IAEA (1981)
- 86 In general, the staff concludes that the effective way to reduce potential groundwater contamination and associated health effects is to reduce the amount of moisture available to carry toxic contaminants away from the impoundments--that is, to control seepage. USNRC (1980a)
- 87 Although the preferred approach towards groundwater protection is isolation of tailings, the staff does not consider complete prohibition of disposal in groundwater appropriate. The conservative approach of providing isolation may be unnecessary where it can be demonstrated that on the basis of site-specific conditions and with tailings treatment, groundwater quality can be preserved. USNRC (1980a)
- 88 Site design for preventing seepage of toxic materials that should be considered include installation of impermeable bottom liners and neutralization to prevent immobilization of toxic substances. USNRC (1980a)
- 89 The EPA proposes to apply groundwater standards only within one km from the pile when an existing site is used for disposal and within 0.1 km at a new disposal site. USEPA (1980d)
- 90 NRC does not anticipate that EPA standard for release of radioactivity to the environment from disposal facilities, when promulgated, will be much higher than that for release to the environment from fuel cycle facilities (25 mrem/yr whole body exposure; 40CFR190) or any lower than that for radioactivity in drinking water (4 mrem/yr whole-body exposure, 40CFR141). USNRC (1981a)
- 91 NRC has selected an objective which requires that any movement of radioactivity not result in calculated doses exceeding 25 mrem/yr to an individual standing at the site boundary or exceeding the EPA Drinking Water Standards at the nearest public drinking water supply. USNRC (1981a)
- 92 Concentrations of radioactive materials in groundwater must not exceed the maximum containment levels established in the National Primary Drinking Water Standards at the nearest public drinking water supply (a limit of 10 pCi/l above background must be used for uranium and thorium). USNRC (1981a)

93 USHRC (1981a)
Areas must be avoided having economically significant natural resources whose exploitation would jeopardize meeting the performance objectives.

94 USHRC (1981a)
The site must be generally well-drained and free of areas of frequent ponding and flooding. [It must not be] in a 100 year flood plain-coastal high-hazard area or wetland.

95 USHRC (1981a)
Upstream drainage areas must be minimized.

96 USHRC (1981a)
[There must be] sufficient depth to the water table that groundwater intrusion, perennial or otherwise-into the waste will not occur. Exceptions will be considered if it can be shown conclusively that the predominant means of radionuclide movement is diffusion slow enough to meet the performance objectives.

97 USHRC (1981a)
Any groundwater discharge to the surface within the disposal site must not originate within the hydrogeologic unit used for disposal.

98 USHRC (1981a)
Site must be designed to eliminate contact of water with waste during storage, contact of standing water with waste during disposal, and contact of percolating or standing water after disposal.

99 Murphy and Holter (1980)
Exposure pathways that may result from hydrological release mechanisms include:
- ingestion of water from a well drilled on the burial site into the shale formation below the waste or ingestion of water from a nearby river
- ingestion of aquatic foods taken from a nearby river contaminated by radionuclides released through the ground water or by overland flow
- ingestion of crops irrigated with contaminated water taken from the river
- direct irradiation from crop fields irrigated with contaminated river water and from soil contaminated by overland flow of radionuclides
- inhalation of resuspended radionuclides deposited on crop fields by irrigation or by overland flow
- ingestion of foods contaminated by the deposition of resuspended irrigation and overland flow deposits.

100 Murphy and Holter (1980)
The conclusion of the Argonne study on migration in aqueous solution-rock systems of migrating nuclides was that the behavior of migrating nuclides in these experiments could not be accurately described by models that predict a single migration rate based on simple absorption properties and local chemical equilibrium. A dispersive model of fluid flow was needed, and models of nuclide migration need to provide for the reaction of individual nuclides.

101 Lester et al. (1981)
Water path sensitivity interactions were aquifer water travel time with nuclide solubility, aquifer water travel time with water body turnover flowrate and nuclide solubility with water body turnover flowrate. The interactions of solubility with travel time or water body turnover are very significant. It means that reasonable site resistance precludes any need to know solubility (nuclides could just as well be in solution) or also that high dilution rates in a body destroys significance of solubility. Perhaps, the need for better understanding of solubility is not always

102 Lester et al. (1981)
Some variables showed insensitivity. In the air path the layering of the solid column was found to be insignificant indicating that the geology of the soil column may not need to be defined in great detail but rather averaged properties could be used. Total column depth causes a pure delay in the output (with nuclide decay superimposed). The population distribution in distance was also relatively insignificant. That is, closeness to the site had little effect for airborne transport. In the water path dispersion in the aquifer had little effect on the results. Since dispersion coefficients are difficult to determine, this is fortuitous.

A.3.2 Geology

1 USEPA (1977b)
For site selection, what is the relative importance of environmental barriers such as geological strata versus engineered controls such as containers?

2 USDOE (1981c)
What effects on soil and mineral resources will disposal operations cause?

3 USEPA (1981d)
Landfill-closure design and post-closure care must consider site location topography and surrounding land use.

4 Macbeth et al. (1978)
Potential problems associated with SLB include possible land reclamation, groundwater leaching and transport, and surface erosion.

5 Lipton (1981)
Faster migration can occur through fractures or other anomalies in the [soil] media.

6 Lipton (1981)
The effectiveness of a monitoring system largely depends on the knowledge of a sites geology and hydrology, [e.g. so] that sampling points are properly placed in relation to possible paths of migration. [GAO,1976]

7 Lipton (1981)
Transport of vapor phase tritium through joints and porous zones has been observed.

- 8 Numerous models [for pathways and migration rates] are available, although inadequate for complete determination, particularly for media with anomalies such as fractures. Lipton (1981)
- 9 The site shall be located where site performance will not be jeopardized by erosion, (by wind, water, or mass wasting). Falconer et al. (1981)
- 10 If [subsurface] fractures are present, fluid loss inhibitions (e.g., grouts) might minimize migration of radionuclides. Deichman (1979)
- 11 Development and evaluating erosion and intrusion control barriers [is a priority technical issue]. [It must be] consistent with abiotic, edaphic, and biotic conditions, and stable over long periods of time. Deichman (1979)
- 12 Determination of sorptive capacities for radionuclides in soil/solution systems [is a priority technical issue]. Deichman (1979)
- 13 Sorptive coefficients should be determined using soil materials and groundwater as they exist at the site. Deichman (1979)
- 14 Detailed study of sorption mechanisms is particularly important for the more hazardous and long-lived radionuclides, to predict their retardation in geologic formations. Deichman (1979)
- 15 Determination of the effects of soil microorganisms on transport and transformation of radionuclide [is a priority technical issue]: Effects of microbial action on solubility, mobility, and bioavailability of radionuclides. Deichman (1979)
- 16 Soil microorganisms may (1) solubilize chemicals in the soil, (2) transform organic wastes into gases, which may be important for release of gaseous forms of C-14 and tritium, (3) may degrade organo-radionuclide complexes, and (4) may influence bioavailability. Deichman (1979)
- 17 Erosion calculations should take into account gully erosion and the effect of disturbance of the land surface on erosion rates. Adam and Rogers (1978)
- 18 After wastes have been placed in trenches, the geologic formation is considered the primary barrier to radionuclide migration. Water is the principal vehicle for radionuclide transport; thus knowledge of the direction, depth of water table, flow paths, rate of movement, and dispersion of water coupled with the mechanisms and degree of interactions of specific radionuclides with the formation are required to understand radionuclide migration. Jacobs et al. (1980)
- 19 In evaluating erosion control measures, consideration should be given to their ability to remain stable over long periods of time and to provide protection against intrusion by deep-rooted plants and by small burrowing animals as well as their effectiveness in providing short-term erosion control. Jacobs et al. (1980)
- 20 Over long time periods, say several millennia, even the solid matrix can move significantly because of erosion or tectonic events. Jacobs et al. (1980)
- 21 Specific items related to water management that need additional research and development emphasis include: (1) field testing and engineering evaluation of techniques for control of infiltration and erosion; and (2) development of a rationale for arriving at a balance between control of infiltration and erosion. Jacobs et al. (1980)
- 22 Disposal site soil should have good ion exchange and sorptive properties, which usually accompanies fine textured material. Macbeth et al. (1979)
- 23 Sites for intermediate depth burial (IDB) are less plentiful than for SLB, but many areas of the country have more than adequate soil depth. Macbeth et al. (1979)
- 24 Many former strip mines are available [for IDB sites], where the recontouring [for erosion control] could be environmentally advantageous. Macbeth et al. (1979)
- 25 Upstream rain catchment areas must be minimized to decrease erosion potential and the size of the maximum possible flood. USMRC (1980b)
- 26 Topographic features should provide good wind protection. USMRC (1980b)
- 27 A full self-sustaining vegetative cover shall be established or a rock cover employed to reduce wind and water erosion to negligible levels. Rock covering of slopes may not be necessary when top covers are very thick or inherently erosion-resistant, slopes are very gentle, and there is negligible upstream rain catchment and good wind protection. USMRC (1980b)
- 28 Ownership of certain severable subsurface interests (for example, mineral rights) may be determined to be unnecessary to protect the public health and safety and the environment. USMRC (1980b)
- 29 The major release mechanisms (and pathways) to man that can occur over time are as follows: erosion and transport to streams (drinking, uptake in fish, irrigation); leaching to aquifer (drinking, irrigation); aquifer to stream (drinking irrigation, fish); intrusion (resuspension); exposure of wastes (resuspension, ingestion in foods). Additional release mechanisms exist, but analysis indicates that, when carried to an extreme, conditions approaching those noted above will be present. Healy (1980)
- 30 In an analysis of a model burial ground, the limiting release mechanism, or the one giving the highest doses, was determined to be the future exposure of wastes in the burial ground with people living in the area. Exposure of the waste by erosion was estimated to take 2000 - 13000 years by sheet erosion although gully erosion could decrease this time as could human action in the area. (Note: the model burial ground was 10 m deep; the cap thickness was not specified.) Healy (1980)

- 31 Deichman (1980)
Models have been developed to evaluate mass and energy balance in the atmosphere and in geohydrologic systems. However, these models do not adequately simulate the migration of radionuclides and water in the geohydrologic system. The inadequacy of simulation is predominantly due to paucity of information concerning the mechanisms influencing transport. Furthermore, most models need to be validated. Quantitative information is needed on the interaction of the waste and the disposal medium to evaluate three-dimensional transport of fluids, gas, particulate matter and radionuclides and for their evaluation using existing predictive models.
- 32 Deichman (1980)
The mechanisms and degree of interaction between radionuclides in groundwater and soil materials depend to a great extent on the predominant chemical and physical forms of the radionuclides in the waste and in the receiving geologic media. The chemical and physical forms are affected by a number of chemical conditions (e.g., electrolyte concentration, oxidation-reduction conditions, pH, presence of complexing agents) which may be variable in both time and space.
- 33 Deichman (1980)
Sorption coefficients provide an index of the degree of interaction between the radionuclide and the soil material and are affected by a number of parameters. Sorption coefficients should be determined using soil materials and groundwater as they actually exist at specific sites. Parameters affecting sorption coefficients should be evaluated.
- 34 Deichman (1980)
Performance assessment of a burial requires field operational analytical systems capable of measuring water and radionuclide transport in the geohydrologic and atmospheric systems. Factors typically affecting water and radionuclide transport include: (1) micrometeorology (e.g., precipitation, evaporation, solar radiation, humidity, temperature), and (2) geohydrology (e.g., temperature, humidity, water content, cation-anion water concentration, redox potential, pH). These parameters are interactive within a complex three-dimensional continuum consisting of the waste burial formation and the atmosphere.
- 35 USNRC (1980a)
Site design features for erosion control that should be considered include: upstream rainfall catchment areas and flood erosion potential; topographic features for wind protection; embankment and cover slopes, with emphasis on avoiding slopes greater than 1:10 (vertical:horizontal); and adequate self-sustaining vegetative cover or rock cover.
- 36 USNRC (1981a)
Areas must be avoided having economically significant natural resources whose exploitation would jeopardize meeting the performance objectives.
- 37 USNRC (1981a)
Areas must be avoided where surface geologic processes such as mass wasting, erosion, slumping, landsliding, or weathering [could] significantly affect [meeting] the performance objectives or preclude defensible modeling and prediction of long-term impacts.
- 38 USNRC (1981a)
Surface features must direct water drainage away from disposal units at velocities and gradients which will not result in erosion requiring future active maintenance.

- 39 Murphy and Holter (1980)
The radionuclide Ra226 presents a unique problem in determining site release conditions and requires separate consideration. The Rn222 daughter is a noble gas and does not bind chemically or physically to the soil.
- 40 Murphy and Holter (1980)
Because site stabilization or waste relocation activities may disrupt site edaphic conditions and vegetation, additions and/or changes in environmental monitoring as compared to the operational monitoring program may be required (e.g., in onsite soil, air, and vegetation sampling).
- 41 Lester et al. (1981)
Some variables showed insensitivity. In the air path the layering of the solid column was found to be insignificant indicating that the geology of the soil column may not need to be defined in great detail but rather averaged properties could be used. Total column depth causes a pure delay in the output (with nuclide decay superimposed). The population distribution in distance was also relatively insignificant. That is, closeness to the site had little effect for airborne transport. In the water path dispersion in the aquifer had little effect on the results. Since dispersion coefficients are difficult to determine, this is fortuitous.
- 42 Lester et al. (1981)
Significant variables of note included weather pattern (dryness, wetness, wind velocity) agriculture in the air path, nuclide quantity in the water path (held constant in the air path), and stack height in the air path. Interactions in the air path included weather (wind and rain) with cap erodibility (geometry of cap), soil size with burial depth, soil size with site wind resistance and burial depth with soil column retardation factor.

A.3.3 Seismology and Volcanology

- 1 USEPA (1981a)
There is need for more precise seismic standards for hazardous waste disposal (burial) sites.
- 2 USEPA (1981a)
Definition of geologic faults may be inadequate. Example: Should concern be about all faults or those just recently formed (Holocene)?
- 3 USEPA (1981a)
Should seismic standards be based on (predicted) earthquake magnitude?
- 4 USEPA (1981a)
What is meant by "weight of geological evidence," and "reasonable probability of being affected by movement along a fault," in defining an active fault zone?

- 5 Should facilities for hazardous waste disposal be allowed within active fault zones even if designed to withstand seismic activity? USEPA (1981a)
- 6 Restrictions of waste disposal facility siting in active fault zones should be based on: (1) degree of hazard waste disposed of and (2) proposed method of disposal. USEPA (1981a)
- 7 The site shall be located where faults, liquefaction, landslides, volcanoes, or land subsidence will not jeopardize site performance. Falconer et al. (1981)
- 8 Areas must be avoided where tectonic processes such as faulting, folding, seismic activity, or volcanism may [jeopardize] the performance objectives or preclude defensible modeling and prediction of long-term impacts. USNRC (1981a)

A.3.4 Meteorology and Climate

- 1 Are the relative advantages of the geology of drier regions great enough to support the tradeoff between the reduced risks at such sites versus the increased risks and cost associated with the transportation of wastes to such regions? USEPA (1977b)
- 2 What changes in the air quality caused by dust and other pollutants, will be caused by disposal operations? USDOE (1981c)
- 3 Owner/operators of new landfill disposal facilities must ensure prevention of adverse effects on air quality. USEPA (1981d)
- 4 Landfill-facility (trench) liner design must consider the climatic conditions in the area. USEPA (1981d)
- 5 Landfill-facility leachate and runoff control systems design must consider climatic conditions in the area. USEPA (1981d)

- 6 Landfill-closure design and post-closure care must consider climatic conditions in the area. USEPA (1981d)
- 7 What level of specificity of information must one have about (buried-) waste constituents in order to predict air dispersion (data)? USEPA (1981e)
- 8 The site shall be located in an area not subject to flooding. This criterion excludes floodplains, coastal areas prone to hurricanes or storm surges, and regulatory floodways. [Also] marshes, swamps, bogs, mudflats, and areas with small enough slopes that precipitation and snowmelt can pond. Falconer et al. (1981)
- 9 The site shall be located in areas where climatological conditions allow reliable performance predictions. Recurrence probabilities of any extreme meteorological events which could threaten site performance shall be predictable with reasonable confidence. Falconer et al. (1981)
- 10 The safety assessment portion [of the environmental and safety report] examines consequences of potential operational accidents, natural disasters, radionuclide migration, and severe climatic conditions. USDOE (1981a)
- 11 If microorganisms are found to have significant effects on radionuclide transport, then potential effects on such microorganisms of climate change, e.g., due to potential "greenhouse effects", may need to be considered. Deichman (1979)
- 12 Factors typically affecting water and radionuclide transport include: (1) micrometeorology (e.g. precipitation, evaporation, solar radiation, humidity, temperature) and (2) geohydrology (e.g. temperature, humidity, water content, cation-anion water concentration, redox potential, pH). Deichman (1979)
- 13 Effect of off-normal weather conditions on burial sites [is an important technical issue]. "Catastrophic" storms likely at burial sites in intervals of decades or centuries [as well as more frequent severe weather conditions] are to be taken into account. Deichman (1979)
- 14 Assessment of the effects of severe weather and/or "catastrophic" storms depends on on-site study in conjunction with the best available information on conditions which may be expected to occur and on the frequency of their occurrence. Literature search for surrogate data, empirical equations for water and wind erosion and experimental tests of such can provide initial assessment. Deichman (1979)
- 15 Determination of the effects of trench construction on geohydrological parameters [is an important technical issue]. Increased permeability and elevation of the water table at the trench [can occur], and potential changes in hydrological parameters should be monitored. Deichman (1979)

- 16 Off-normal weather conditions are of concern in developing a water management policy. For locales where abnormal weather conditions are dramatically different from normal occurrences, management policy may need to be weighted toward a concern for the abnormal. Jacobs et al. (1980)
- 17 Ideally, precipitation at the site should be low, distances to aquifers should be long, aquifer flows and utilization should be low, and underlying strata should be neither highly fractured nor contain voids or flow channels. Macbeth et al. (1979)
- 18 In areas having heavy rainfall, the use of a movable structure for a weather shield during trench filling operations may be useful. Macbeth et al. (1979)
- 19 Improved overall weather shielding, e.g. a weather shield building during trench filling and moisture barriers over the pits, could decrease the importance of adverse climatic conditions in site selection. Macbeth et al. (1979)
- 20 In analysis for a generic land disposal facility, the standard Gaussian Plume method has been used to model transport of airborne release following a container rupture accident. Macbeth et al. (1979)
- 21 Topographic features should provide good wind protection. USNRC (1980b)
- 22 Because site stabilization or waste relocation activities may disrupt site edaphic conditions and vegetation, additions and/or changes in environmental monitoring as compared to the operational monitoring program may be required (e.g., in onsite soil, air, and vegetation sampling). Murphy and Holter (1980)

A.3.5 Ecology

- 1 What will be the effects of disposal operations on plants and animals? USDOE (1981c)
- 2 Compounds should be designated hazardous only if they are known to persist in the aquatic environment. USEPA (1980b)
- 3 Plants growing above buried waste may absorb significant quantities of radioactive material, e.g., Sr-90 uptake at Savannah River Laboratory backfilled trenches. Lipton (1981)
- 4 Shallow-rooted grass barriers may, in natural ecological succession, be invaded by deep rooted trees and shrubs. Deichman (1979)

- 5 Much pertinent information on the climax situation representative of each site may be available from studies of abandoned farmlands or other disturbed areas near the site. Deichman (1979)
- 6 Determination of the effects of soil microorganisms on transport and transformation of radionuclide [is a priority technical issue]: Effects of microbial action on solubility, mobility, and bioavailability of radionuclides. Deichman (1979)
- 7 Soil microorganisms may (1) solubilize chemicals in the soil, (2) transform organic wastes into gases, which may be important for release of gaseous forms of C-14 and tritium, (3) may degrade organo-radionuclide complexes, and (4) may influence bioavailability. Deichman (1979)
- 8 If microorganisms are found to have significant effects on radionuclide transport, then potential effects on such microorganisms of climate change, e.g., due to potential "greenhouse effects", may need to be considered. Deichman (1979)
- 9 A consideration of the ecological factors is necessary for the investigation in order to: (a) predict environmental impacts caused by the establishment and operation of a repository, in terms of the biological, chemical and physical components; (b) assess the potential effects (both adverse and beneficial) caused by the disposal of materials at the site, by displacements arising from the disposal activity, and by other changes from previous conditions within the site area and in the surrounding areas; (c) evaluate the relative significance of such changes and effects on the ecology as an aid in site selection. The presence of rare or unique species or ecosystems also affect the selection or rejection of a particular site. IAEA (1981)
- 10 The biological action of root uptake of radionuclides from the buried waste and from waste in the topsoil may establish a link to humans via the ingestion of locally grown crops. Ecological pathways involving the movement of waste material by waterfowl, burrowing animals, blowing weeds, etc., are not considered in this study. Murphy and Holter (1980)
- 11 Because site stabilization or waste relocation activities may disrupt site edaphic conditions and vegetation, additions and/or changes in environmental monitoring as compared to the operational monitoring program may be required (e.g., in onsite soil, air, and vegetation sampling). Murphy and Holter (1980)
- 12 In 1966, downriver from a Durango tailings pile, the Animas carried three times the concentrations of radium 226 and strontium 90 permissible in drinking water. Even more alarming than these measurements were the levels of isotopes recorded in the cells of water organisms: The radium isotope was measured in river plants and creatures at up to ten thousand times its concentration in the river. This meant that as the radium was passed up the food chain from river plant to fish-it became more concentrated, and thus more dangerous. Shapiro (1981)

In 1979, after Hurricane David, Louis G. Williams, an emeritus professor of ecology at the University of Alabama in Tuscaloosa, reported monitoring the passage of a "slug" of Tennessee River organisms contaminated by concentrations of cobalt six thousand times as high as normal fallout measurements and by concentrations of strontium and cesium eight thousand to ten thousand times as high.

A.4 SOCIOECONOMICS

- 1 USDOE (1981a)
Screening based on field reconnaissance will investigate geology and topography, hydrology and meteorology, seismology and volcanology, socioeconomics and land use, ecology, soil types.
- 2 USDOE (1981b)
Besides direct socioeconomic impacts of a disposal site on surrounding communities, there are secondary effects [whose] importance is usually underestimated.
- 3 IAEA (1981)
The factors relating to the social and economic aspects of shallow ground disposal are frequently difficult to measure or quantify, but they are important and can be decisive aspects of the site selection. The more important considerations include the following factors: (a) proximity to sources of waste, (b) adequacy of transport systems, (c) resources foregone by the commitment of land to waste disposal, (d) population density, (e) ownership and use of the land, (f) impact upon the community (e.g., employment) and (g) political constraints (including acceptance).

A.4.1 Cultural Resources

- 1 USDOE (1981c)
How will waste disposal effect scenic, historic, and cultural resources?
- 2 Falconer et al. (1981)
The site shall be selected with consideration given to current and projected land use and resource development. It shall not be unique in its economic or esthetic value for industrial, agricultural, or recreational uses. It shall not prevent recovery of fuel, mineral, or water resources of present or potential economic value. Burial within an aquifer is unacceptable.
- 3 USDOE (1981d)
Because archaeological sites were suspected in the area, Plains Electric began working closely with the State Historic Preservation Officer early in the planning stages. Results of preliminary surveys indicated those areas where presence of archaeological resources was most probable. Plains Electric, Rural Electrification Administration, the New Mexico State Historic Preservation Officer, and members of the Advisory Council for Historic Preservation consulted and prepared a Memorandum of Agreement which outlines the course that Plains Electric will follow to migrate the impacts to the resources. By planning in advance and by developing a well-thought-out mitigation strategy, Plains Electric has found that the construction schedule will not be disrupted. They have also found that by coordinating frequently and openly with the scientific community and the State Historic Preservation Officer, consultation and decisions on mitigation strategies are accomplished quickly.

- 4 USDOE (1981d)
A more serious problem arose because various Indian groups declared that sacred burial grounds and cultural resources existed in the area. They insisted that these sites could not be touched under any condition. Unfortunately, not only would the trenching activities impact on these sites, but these sites are often times disturbed by the archaeologists engaged in data recovery operations. The problem with the Indian cultural sites was unmitigable because the Indians demanded that the site not be touched. Because the seismic study required extensive trenching activity, impacts were inevitable. Since there are no regulations governing these types of problems the battle had to be fought in the courts. The UHS Terminal Associates won, but at the expense of delays to the seismic studies. There was also some problem with acquiring a State archaeologist to monitor and recover the data since the Indian groups requested that no archaeologist participate. Many archaeologists honored the Indian's request; however, a qualified individual was finally found.

A.4.2 Demography

- 1 USDOE (1981c)
How will waste disposal change population or effect housing, social structure, services, and economic structure near the site?
- 2 Falconer et al. (1981)
The site shall be selected with consideration given to current and projected population distributions. (Effects of accidental and chronic radiation releases, likelihood of human intrusion, etc.)
- 3 USDOE (1981a)
Preliminary site screening is to determine whether a state or region can site a facility at all. Finding a suitable site in an area is less likely if it contains one or more of the following: wetlands, shallow groundwater tables, high precipitation and low runoff, flood plains, large population, or valuable lands.
- 4 Macbeth et al. (1979)
Important site selection factors are: site availability, distances to ground and surface meteorology and climatology, degree of remoteness, geologic stability, proximity to sources of waste and ownership for long-term control.
- 5 Macbeth et al. (1979)
Non-radiological impacts from constructing an SLG on a site which is undesirable for other uses and remote from population centers would be small. Routine hazards to workers would be comparable to those in general construction and in surface mining.
- 6 USNRC (1980b)
In selecting among alternative tailings disposal sites or judging the adequacy of existing sites, the extent to which a program meets the broad [NRC] objectives depends on:
 - . Remoteness from populated areas.
 - . Immobilization and isolation of contaminants from usable groundwater sources, (as provided by) hydrologic and other natural conditions.
 - . Potential to minimizing erosion, disturbance.
 - . Dispersion by natural forces over the long term.

- 7 USNRC (1981a)
A disposal site should be selected so that projected population growth and future developments are not likely to affect the ability of the site to meet the performance objectives.
- 8 Lester et al. (1981)
Some variables showed insensitivity. In the air path the layering of the solid column was found to be insignificant indicating that the geology of the soil column may not need to be defined in great detail but rather averaged properties could be used. Total column depth causes a pure delay in the output (with nuclide decay superimposed). The population distribution in distance was also relatively insignificant. That is, closeness to the site had little effect for airborne transport. In the water path dispersion in the aquifer had little effect on the results. Since dispersion coefficients are difficult to determine, this is fortuitous.

A.4.3 Economic Costs.

- 1 USEPA (1981a)
Should cost-effectiveness be considered in waste-disposal rulemaking, or should health protection be more important than cost?
- 2 USEPA (1981a)
Is shallow-land waste burial too expensive, or the only practical approach at present?
- 3 USEPA (1981a)
Should the procedure for rulemaking consider cost effectiveness analysis or risk/benefit evaluations? Should a dollar value be established for health-effect mitigation?
- 4 USEPA (1977b)
Are the relative advantages of the geology of drier regions great enough to support the tradeoff between the reduced risks at such sites versus the increased risks and cost associated with the transportation of wastes to such regions?
- 5 USEPA (1978)
Should regulatory considerations attempt to address the designation of no resource or product value, and who should make that decision?
- 6 USEPA (1978)
Public health, safety, and full-cost analysis are all essential components in the consideration of waste-disposal controls.
- 7 Levin (1980)
Regulations and incentives should be combined to encourage optimal LLW treatment techniques.
- 8 Macbeth et al. (1978)
[In] commercial site selection, the final decision [is] based on hydrogeological and economic factors.
- 9 USDQOE (1980c)
[A] regional[compact] approach is preferable to federal preemption or 50 separate sites, based on considerations of cost, transportation, political issues, and health and safety factors. [HSA]
- 10 USDQOE (1980c)
Assuming that some of the smaller batches of FUSRAP wastes can be accommodated in existing sites without major impact on future disposal at those sites, what are the tradeoffs in economic costs between disposal at an existing site and interim storage with eventual disposal at a new site?

- 11 USDQOE (1980b)
Regional disposal sites for remedial action wastes is a preferred disposal option.
- 12 Lipton (1981)
A Dames and Moore report emphasizes the use of hydrogeological modeling to determine cost-effective placement of monitoring wells.
- 13 Lipton (1981)
The numbers and placement of monitoring devices should be based both on available information on potential migration pathways and on cost-benefit considerations.
- 14 Lipton (1981)
Problems with SLB have occurred, not because they are inherently incurable, but rather, because they were not properly identified and confronted:
(1) The early sites claimed zero release, which is neither feasible nor necessary.
(2) There was little interest among top level scientists in studying this field.
(3) Waste disposal was considered a necessary evil to be accomplished as cheaply as possible.
- 15 USDQOE (1981b)
Classification by total hazard is deemed desirable by the states, which [should] enhance development of regional compacts and disposal sites, and it should achieve greater protection of the public than any alternative classification scheme. However, costs of waste management and disposal would increase substantially, and regulation development and enforcement would significantly impact on regulatory agencies.
- 16 Adam and Rogers (1978)
What is the appropriate person-rem/dollar tradeoff that should be used in assessing relative cost-benefits for different near-surface disposal sites and comparing them with the stabilization-in-place alternative?
- 17 Macbeth et al. (1979)
Public acceptance, major concerns:
Perception of risk versus hazards:
Adequate information and understanding of risk assessment and cost-benefit tradeoffs. Definition of acceptable risks to public health and safety and the environment.
- 18 Macbeth et al. (1979)
Engineering improvements, e.g. in weather shielding, may offer risk/cost/benefit tradeoffs against transportation costs and risks.
- 19 USNRC (1980b)
Primary emphasis shall be given to long term isolation of tailings or waste as opposed to short term convenience or benefits such as minimization of transportation or land acquisition costs.
- 20 Deichman (1980)
Intermediate-depth burial (IDB) would position the waste farther from plant root systems and fauna than does shallow land burial (SLB) and reduce the potential for exposure by erosion and intrusion by humans. These advantages should be weighed against the increased cost, reduced distance between waste and the water table, and the alternative of placing more effective barriers in trench covers of conventional SLB trenches.
- 21 USNRC (1981a)
In response to NRC advance notice of proposed rulemaking many commenters advocated a system for classifying or segregating LLW according to hazard, and the most often expressed disadvantage of any alternative disposal method was potential for increased cost.

- 72 Perhaps the only viable site release option for existing sites that contain significant inventories of long-lived radioisotopes is conditional release with land use restrictions and administrative control of the site. Murphy and Holter (1980)
- 23 One tailings and low-level radioactive waste from the nuclear industry need a sound program of environmental protection to ensure that they do not present significant health risks to the public. Since even the worst-case risks from these sources are quite low, the steps required should be based on the most probable values of costs and risks, rather than on the most conservative possible assumptions. (1) Statement 5-12, by J.P. Holdren: I disagree. Conservatism is particularly appropriate when the potential victims are in future generations, as is the case with tailings and low-level wastes. National Acad. of Sci. (1979)

A.4.3.1 Specific Issues

- 1 Would there be any benefit derived from reprocessing the waste materials to recover minerals? USDOE (1981c)
- 2 What costs and burdens are associated with developing adequate data necessary to confidently predict volume rate, and concentration of air (gaseous) emissions (from a waste-burial site)? USEPA (1981e)
- 3 What costs and burdens are associated with accurately predicting (buried-) waste constituents migration in the air? USEPA (1981e)
- 4 What costs and burdens are associated with accurately predicting near- and long-term exposures (to disposed wastes)? USEPA (1981e)
- 5 When published (waste-disposal) regulations, criteria or well-documented studies are unavailable, what is the cost of conducting tests (research) adequate to demonstrate probable health effects? USEPA (1981e)
- 6 Is disposal in man-made structures an acceptable and cost-effective alternative for some FUSRAP waste? Macbeth et al. (1978)
- 7 Location of disposal site, either in-state or regional (is a key issue affecting costs and schedule). USDOE (1980b)
- 8 Type of disposal-site ownership, based on either government financing or commercial rates (is a key issue affecting costs and schedule). USDOE (1980b)
- 9 Transportation of contaminated material to a disposal site may be a significant factor in the cost of remedial action, and the major factor in the [transportation] cost is the distance for transport. USDOE (1980b)
- 10 Operating costs will be affected by whether the [disposal] site is a single-use or a multiple-use site. USDOE (1980b)

- 11 Evaluation of the technical feasibility of Intermediate Depth Burial (is a priority technical issue). In comparison to SLB, for example, there is increased isolation of waste, greater operational costs, decreased distance to water table. Deichman (1979)
- 12 Can the methodology used to analyze the cost-benefit consequences of changing the defining interface between nonradioactive waste and low-level radioactive waste be used to help resolve the issue of whether FUSRAP waste at a particular site could be stabilized in place rather than moved to a near-surface disposal facility? Adam and Rogers (1978)
- 13 Waste relocation involves the exhumation of buried waste, repackaging of the waste if necessary, and reburial of the waste at another disposal site or in another trench on the same site. Exhumation of waste originally buried without any intent of later retrieval is an expensive and time-consuming operation that has a potential for significant radiation exposure to decommissioning workers. Therefore, waste relocation would likely be considered only in situations where other decommissioning procedures are inadequate to ensure that future risk from the facility is within acceptable bounds. Murphy and Holter (1980)
- 14 In general, it is believed that long-term care funds provide sufficient money for routine maintenance and surveillance of a retired site, but are not adequate for extensive corrective actions should the need arise. Murphy and Holter (1980)
- 15 An important concern regarding sinking fund financing is that sufficient fund for site stabilization and long-term care may not have been collected if the site closes prematurely. Murphy and Holter (1980)
- 16 In view of the large quantities of relatively low activity materials and considerations such as the need for overburden and tailings as replacement for mined volumes, the potentially recoverable phosphate and uranium resources of dewatered clays, and the superiority of furnace slag to other materials locally available as aggregates, it is neither practical nor prudent to ship these materials to off-site burial grounds as is done with small quantities of "conventional" low level radioactive waste from the nuclear industry and nuclear research. Roessler et al. (1979)
- 17 Capital costs to construct the disposal facility are much less dependent upon the volumes of waste delivered to the facility than the operating costs. Many of the same expenses to design, build, and operate the facility would be incurred whether a high or low volume of waste was received. USNRC (1981b)
- 18 Half the respondents to the Advance Notice offered a comment on ocean dumping and most were against it as an alternative for LLW disposal. The major perceived disadvantages are the probability of severe ecological damage, international repercussions, and the issue of dispersal versus containment. The only advantage seen by the respondents appeared to be the comparatively lower cost of disposal. USNRC (1981b)

19 USNRC (1981b)
Commentors who offered an opinion on Intermediate Land Burial as an LLW method were divided. The comment offered most frequently was that the bulk of the waste would be contained longer, but the increased cost would not be justified by the relatively insignificant hazard.

A.4.3.2 Prescriptive Comments

- 1 USEPA (1980a)
Cleanup standards should be cost-related. The cost should be related to the amount of injury prevented.
- 2 Levin (1980)
Incentives should be offered to facilitate siting LLW facilities.
- 3 USDOE (1980b)
Risk, benefit, and cost analysis of each remedial action and disposal option will be considered in selection of the proposed remedial action, and [will cover] environmental, technical and public opinion issues.
- 4 Falconer et al. (1981)
To the extent consistent with other criteria, the site shall be selected with consideration given to location of waste generators, access to all-weather highway and rail-routes, and access to utilities.
(to minimize transportation costs and risks)
- 5 USDOE (1981b)
While volume reduction is hardly possible for most FUSRAP wastes, minimization of the volume of new waste generated by remedial actions is desirable. Procedures tending to achieve minimization should be adopted when cost/benefit assessment so indicates.
- 6 Macbeth et al. (1979)
A structural disposal facility (SDF) would be built of reinforced concrete, for greatest durability and fire resistance at reasonable cost. Both exposed and covered structures could be built, at any appropriate location.
- 7 USNRC (1980b)
To avoid proliferation of small disposal sites and to reduce perpetual surveillance costs, by product-material shall be disposed of at existing tailings disposal sites unless [it can be shown that] transportation costs and risks [or other countervailing considerations] clearly outweigh benefits of reduced surveillance obligations.
- 8 USNRC (1980a)
The staff considered but determined it would be impracticable and inappropriate to make a fully monetized, incremental cost-benefit optimization the basis for establishing limits on radon flux, given the complex, multi-dimensional and long-term nature of the mill tailings disposal problem.
- 9 USNRC (1980a)
In order to support a cost-benefit balance approach to radioactive emission control, the following basic factors must be established and there is either considerable uncertainty or widely varying judgments as to the appropriate value for each: (1) the period of time over which health effects should be integrated; (2) the economic or monetary value of averting health effects; (3) factors relating health effects to radioactive emission, that is, prediction of resulting health effects per unit of radioactive release; and (4) the costs of providing emission control and the effectiveness of such control in reducing emissions.

10 USNRC (1981a)
An applicant for license must provide, prior to commencement of operations, assurance that sufficient funds will be available for the disposal site closure and stabilization, including decontamination or dismantling facility structures, and such operations or activities as are needed to ensure that no active maintenance will be needed during the postclosure period.

A.4.3.3 Liabilities (Who Pays)

- 1 USDOE (1979)
All costs of waste disposal should be paid by the generators of the waste and borne by the beneficiaries.
- 2 USDOE (1979)
The federal government must be prepared to pay whatever costs are required for waste disposal.
- 3 USDOE (1979)
The costs of remedial actions involving D&D and uranium mill tailings should be included in the cost recovery calculations for commercial waste disposal.
- 4 Levin (1980)
DOE should initiate a study to clarify liabilities in all waste management sectors.
- 5 USDOE (1980c)
Most long-term care funds have been deemed insufficient to cover projected costs: costs have escalated faster than capital accrues through interest, and funds have been needed for corrective action.
- 6 USDOE (1980b)
The state is to identify candidate disposal sites for subsequent study during the [preliminary] engineering and environmental evaluation. DOE would support screening studies.
- 7 USNRC (1981a)
NRC has received evidence of a great deal of public interest concerning the issue of financial responsibility for closure of a disposal site, through both numerous written comments on the preliminary draft regulation and the four regional workshops held to review it.
- 8 Valore and Lamarsh (1978)
The extent to which each state should be responsible for its own radioactive waste is a political issue which will only be solved by the political process as the exigencies of the situation require. In any case, the licensing and monitoring of waste disposal sites should remain within the province of the Federal Government. Independent monitoring of such sites can and should be carried out by state and local authorities.
- 9 Lash (1979)
NRC recommends: the establishment of fees at a level which assures adequate funds for long-term care for each cubic foot of waste buried; and the payment of fees by persons that produce long-lived wastes to finance adequately safe permanent disposal.
- 10 Lash (1979)
It is far from clear that every state has sites that will safely store low-level wastes, and proliferation of sites to 50 is undesirable from a managerial point of view. Sources of LLW cover a wide variety of activities, and the people who benefit from them are not always residents of states in which these activities occur. A state should not necessarily bear the major responsibility for disposal of wastes produced within its borders.

A.4.3.4 Specific Estimates and Comparisons

- 1 Macbeth et al. (1978)
Disposal costs for any alternative method would be small fraction of cost of electricity generation.
- 2 USDOE (1980b)
The basis of the [preliminary] cost estimates for remedial action assumes contamination would be reduced to 5 picocuries of radium-226 per gram of soil (as comparable levels for other radionuclides), which is in the range of 2 to 10 times natural background.
- 3 USDOE (1980b)
Packaging contaminated material [in] containers such as 55 gallon drums [leads to] costs for handling and transport [which are] three of four times greater [than those] for shipment by bulk transporters such as large-volume trucks or railroad cars.
- 4 Deichman (1979)
Development of instrumentation for in-situ physical chemical characterization of buried waste [would be quite desirable]. However a high cost/benefit ratio and restricted utility is probable.
- 5 USDOE (1981b)
Classification by radiological hazard would: increase costs of waste management disposal, increase occupational risk for generator employees but decrease public risk, require new regulations (except for transportation), and enhance incentives for interstate compacts and new site development.
- 6 USDOE (1981b)
Enforcement and inspection of transportation regulations could cost a state's agencies between \$50K and \$100K a year.
- 7 USDOE (1981b)
The cost/benefit analysis for the numerical guidelines developed [in WASH-1253] criterion is out of date and may no longer be reasonable because of rapid escalation of waste management costs. Additional environmental releases would be considered ALARA.
- 8 USDOE (1981b)
Generic cost analysis for SLB (Macbeth 1979) include costs for transportation, return on investment, money and profits, monitoring and surveillance for 150 years after closure. Transportation dominates in cost differences between eastern and western sites for all disposal concepts.
- 9 USDOE (1981b)
Actual costs of disposal at both existing new sites will probably be much higher than predicted [by Macbeth].
- 10 USDOE (1981b)
Disposal costs (exclusive of transportation) are not overly sensitive to the higher costs for deeper burial or even mined cavity disposal of part of the LLW so long as that part is only, say, 10% of the total waste.

- 11 Adam and Rogers (1978)
The value of \$1000/person-rem/year has been used for assessing the tradeoff between occupational or public doses and the cost of mitigation measures for reducing these doses.
- 12 Macbeth et al. (1979)
Transportation costs and impacts dominate comparisons between eastern and western [disposal] sites, leading to the conclusion that regional sites are desirable.
- 13 Macbeth et al. (1979)
For comparisons of alternatives, no costs common to all disposal alternatives and borne by waste generators are included in Macbeth's cost estimates, which therefore do not represent actual cost.
- 14 Macbeth et al. (1979)
Macbeth's cost estimates include:
The cost for the alternative concepts are estimated in 1978 dollars with provisions for escalation and inflation during the period of operation.
Cost for capital investment return, time value of money and profit are included.
Institutional control over all land disposal sites is assumed to continue for 150 years following termination of waste disposal activities. This is the period of time for which monitoring and surveillance costs are estimated.
- 15 Macbeth et al. (1979)
Disposal of LLW generated in nuclear power production is estimated to cost a consumer about 0.05% to 0.1% of the base generating costs.
- 16 Macbeth et al. (1979)
Incremental costs for the improvements to SLB discussed would amount to 1% to 3% of the total of LLW disposal.
- 17 Macbeth et al. (1979)
The incremental costs for IDB as compared to those of SLB are about 10% of the total disposal costs, and the incremental waste management costs (s.e., economic impact) are also about 10% of the total.
- 18 Murphy and Holter (1980)
Reference SLB site stabilization cost estimates (1978 dollars) range from about \$0.5m for minimal plan at an arid western site to about \$5.5m for a complex plan at a humid eastern site.
- 19 Murphy and Holter (1980)
Estimated time required to relocate the waste from an entire reference burial ground range from 20 to 25 years.
- 20 Murphy and Holter (1980)
Deep geological disposal charges assumed in this and other studies are about one order of magnitude higher than for SLB.
- 21 USDOE (1981d)
Plains Electric is dedicated to protecting the cultural resources of New Mexico and have already invested over \$200,000 in surveys and archaeological mitigation.

A.4.4 Land Use

- 1 Should controls be implemented to prevent the use of low-level waste disposal sites for purposes other than those for which they were planned? Is it feasible to prevent relocation of such sites? Is this of major concern? For how long? USEPA (1977b)
- 2 Institutional control of waste disposal shall cease when there is no longer any need to restrict land use. USEPA (1978)
- 3 What changes in land use will disposal cause? USDOE (1981c)
- 4 How will waste disposal change population or effect housing, social structure, services, and economic structure near the site? USDOE (1981c)
- 5 What assumptions can one make about future groundwater and surface-water use and of land-use patterns in order to predict future exposures (to disposed waste)? USEPA (1981e)
- 6 Incentives should be offered to facilitate siting LLW facilities. Levin (1980)
- 7 What experience has there been, either in the U.S. or elsewhere, in utilizing old strip mines for LLW disposal? Macbeth et al. (1978)
- 8 Unrestricted [post-closure] use is unrealistic, and restricted use acceptability needs be addressed. Macbeth et al. (1978)
- 9 [In] commercial site selection, the final decision [is] based on hydrogeological and economic factors. Macbeth et al. (1978)
- 10 Deeper land burial would [open] the possibility of reclaiming old strip mines or other poor terrain. Macbeth et al. (1978)
- 11 Potential problems associated with SLB include possible land reclamation, groundwater leaching and transport, and surface erosion. Macbeth et al. (1978)
- 12 Controls over disposal sites may permit some beneficial land use, such as making the area into a park where no permanent structures may be constructed. USDOE (1980b)
- 13 The site shall, (1) be of sufficient area and depth to accommodate the projected volume of waste and the buffer zone, and (2) include a 3-0 buffer zone of sufficient size to allow unrestricted human use beyond its boundary-including withdrawal of water from aquifers. Falconer et al. (1981)
- 14 The site shall be selected with consideration given to current and projected land use and resource development. It shall not be unique in its economic or esthetic value for industrial, agricultural, or recreational uses. It shall not prevent recovery of fuel, mineral, or water resources of present or potential economic value. Burial within an aquifer is unacceptable. Falconer et al. (1981)
- 15 Preliminary site screening is to determine whether a state or region can site a facility at all. Finding a suitable site in an area is less likely if it contains one or more of the following: wetlands, shallow groundwater tables, high precipitation and low runoff, flood plains, large population, or valuable lands. USDOE (1981a)
- 16 Technical and economic factors affecting licensing and site design include requirements for: design, pre-operational monitoring, waste acceptance, operations and environmental modeling, closure, operational and extended care funding. USDOE (1981a)
- 17 Much pertinent information on the climax situation representative of each site may be available from studies of abandoned farmlands or other disturbed areas near the site. Deichman (1979)
- 18 Important site selection factors are: site availability, distances to ground and surface meteorology and climatology, degree of remoteness, geologic stability, proximity to sources of waste and ownership for long-term control. Macbeth et al. (1979)
- 19 Non-radiological impacts from constructing an SLBF on a site which is undesirable for other uses and remote from population centers would be small. Routine hazards to workers would be comparable to those in general construction and in surface mining. Macbeth et al. (1979)
- 20 Sites for intermediate depth burial (IDB) are less plentiful than for SLB, but many areas of the country have more than adequate soil depth. Macbeth et al. (1979)
- 21 Many former strip mines are available [for IDB sites], where the recontouring [for erosion control] could be environmentally advantageous. Macbeth et al. (1979)

- 22 Macbeth et al. (1979)
Because deeper burial provides greater isolation of the wastes from the human environment, and because of the possibility of using strip mines or other land unsuitable for more productive use, IDB may be more acceptable to the public than SLB.
- 23 USNRC (1980b)
Ownership of certain severable subsurface interests (for example, mineral rights) may be determined to be unnecessary to protect the public health and safety and the environment.
- 24 USNRC (1980b)
If the commission subsequent to title transfer determines that use of the surface or subsurface estates or both will not endanger the public health, safety, welfare, or environment, the commission may permit the use of the surface or subsurface estates or both.
- 25 Deichman (1980)
A potential radiological hazard from buried waste persists for a considerable period beyond the time when wastes are placed. Unrestricted decommissioning of the site will not be permissible until it can be shown that further control and surveillance are no longer required.
- 26 IAEA (1981)
The past, present and potential future use of land should be investigated so that the compatibility with the requirements for disposal of radioactive wastes can be ascertained. The more important considerations include the following factors: (a) transport systems, (b) water resource management, (c) potential mineral resources, mining claims and operations, (d) agriculture, (e) outdoor recreation, (f) especially designated areas and those of special interest, and (g) government land use plans, zoning and encumbrances (e.g., rights of way easements, etc.).
- 27 USNRC (1981a)
A disposal site should be selected so that projected population growth and future developments are not likely to affect the ability of the site to meet the performance objectives.
- 28 USNRC (1981a)
Areas must be avoided having economically significant natural resources whose exploitation would jeopardize meeting the performance objectives.
- 29 USNRC (1981a)
The site must not be located where nearby facilities or activities could adversely impact [meeting] the performance objectives or significantly mask the environmental monitoring program.
- 30 Murphy and Holter (1980)
Uses that may be considered for a decommissioned [i.e., burial ground fall] under the general categories of restricted use, conditional use, and unrestricted use. The restricted-use category permits reuse of facilities and land for nuclear activities only. The conditional-use category is an interim category that permits limited public use of the burial ground without disturbing the waste assuming that controls to ensure public safety can be adequately enforced. Unrestricted use means that the potential exposure to members of the public from any radioactive wastes remaining buried on the site will not exceed the annual dose limit that may be established by U.S. regulatory agencies. One objective of decommissioning is to achieve the eventual unrestricted release of land areas that the public had been denied use of during normal operations! Use of the burial ground.
- 31 Murphy and Holter (1980)
To allow unrestricted release following the decommissioning of future burial grounds, it may be necessary to limit the type, quantity, and chemical and physical form of the radionuclides buried at these sites.
- 32 Murphy and Holter (1980)
Decommissioning modes for SLB sites correspond to those for fuel cycle facilities as follows: waste relocation/disposal, stabilization/enclosure, and long-term care/safe storage. Definitions of actions, facility status, and land use category for these modes are given by Murphy and Holter in Table 4.1-1.
- 33 Murphy and Holter (1980)
Perhaps the only viable site release option for existing sites that contain significant inventories of long-lived radionuclides is conditional release with land use restrictions and administrative control of the site.
- 34 USDOE (1981d)
The Tioga Mine Drainage Abatement Project (Ward Township, PA.) and Absaroka Coal Mine (Big Horn County Montana) provide important experience in control or mitigation of water pollution problems, and have significantly influenced current mining regulations. It may be noted that more than 592,000 cubic yards of fill were used in reclaiming strip mine pits in Tioga.
- 35 USDOE (1981d)
In 1975, pursuant to state and federal regulations, the Bear Creek Uranium Co. submitted a plan to reclaim and revegetate disturbed lands continuously throughout the life of the project. Topsoil removed from each mined area is segregated from overburden, and is either stockpiled or placed directly on graded and contoured areas. The company grades all waste dump and pit backfill areas to blend with adjacent topography and to provide a positive drainage for runoff. It will also leave a portion of one pit and all of another as water impoundments for livestock and wildlife use, and as a potential irrigation source for local ranches. After milling operations shut down, the tailings will be covered with 10-16 feet of overburden whose surface will be compatible with the natural land. Six inches of topsoil will be applied, seeded, and mulched. Fencing will keep people and livestock away from the reclaimed tailings area until Wyoming's Department of Environmental Quality finds surface radiation levels safe for unrestricted grazing. Visual surveillance of the site will continue over the long term. Finally, ranch owners have negotiated individually with the company regarding financial and other compensations for the loss of their grazing land. The company seeks to minimize its impacts on water supplies by providing water to ranches from other sources.

- 35 Significant variables of note included weather pattern (dryness, wetness, wind velocity) agriculture in the air path, nuclide quantity in the water path (held constant in the air path), and stack height in the air path. Interactions in the air path included weather (wind and rain) with cap erodibility (geometry of cap), soil size with burial depth, soil size with site wind resistance and burial depth with soil column retardation factor. Lester et al. (1981)

A.4.5 Noise

- 1 What changes in noise level will occur during disposal actions? USDOE (1981c)

A.4.6 Public Concerns and Perceptions

- 1 The waste-disposal risk assessment should include a survey of public opinion and, further, dissemination of the assessment results to the public. USEPA (1978)
- 2 Is the scope of public concerns as presently suggested considered adequate for development of standards? USEPA (1978)
- 3 How are public concerns to be used by standard-setting agencies in the development of their individual regulations and general rulemaking? USEPA (1978)
- 4 The IRG and DOE should sponsor nationwide TV debates on waste-disposal management issues. USDOE (1979)
- 5 Decommissioning is unlikely and would depend on how much D&D is needed. Include its consideration to assure the public that all aspects have been examined. Macbeth et al. (1978)
- 6 Public hazard should be ALARA. Macbeth et al. (1978)
- 7 Is disposal in manmade structures an acceptable and cost-effective alternative for some FUSRAP waste? Macbeth et al. (1978)
- 8 It is essential that all aspects of the waste management be conducted with the fullest possible disclosure to and participation by the public and the technical community. USDOE (1980c)
- 9 Congress should pass legislation authorizing states to enter into interstate compacts to establish regional disposal sites. Such authorization is necessary to exclude waste generated outside the region from the regional disposal site. [NGA] USDOE (1980c)
- 10 Regional disposal sites for remedial action wastes is a preferred disposal option. USDOE (1980b)

- 11 Scoping identification of alternative remedial actions and candidate disposal sites will involve affected state and local authorities, EPA, NRC and other appropriate agencies. The principal issues to be examined will be identified, and responsibilities, schedule, and interfaces for conducting necessary studies will be agreed upon. USDOE (1980b)
- 12 Results of preliminary engineering evaluation, environmental analysis, and DOE conclusions as to preferred waste disposal option and reasonable alternatives will be communicated, for review and comment, by DOE to appropriate federal, state and local agencies and to the public. USDOE (1980b)
- 13 Risk, benefit, and cost analysis of each remedial action and disposal option will be considered in selection of the proposed remedial action, and [will cover] environmental, technical and public opinion issues. USDOE (1980b)
- 14 DOE will develop its proposals for waste disposal options on a basis of interagency and public review [of preliminary evaluations and conclusions]. USDOE (1980b)
- 15 A final report on each remedial action and all supporting documentation will be stored in Federal Archives, and copies or summaries placed in records of appropriate local and state agencies. USDOE (1980b)
- 16 After January 1, 1986 any [regional disposal] compact may restrict the use of the regional disposal facilities to the disposal of LLRW generated within the region. Lipton (1981)
- 17 Problems with SLB have occurred, not because they are inherently insurmountable, but rather, because they were not properly identified and confronted:
(1) The early sites claimed zero release, which is neither feasible nor necessary.
(2) There was little interest among top level scientists in studying this field.
(3) Waste disposal was considered a necessary evil to be accomplished as cheaply as possible. Lipton (1981)
- 18 Future monitoring programs must
(1) verify compliance with accepted standards
(2) identify potential problems in time to prevent any adverse public impact, and
(3) provide public assurance of the safety of SLB. USDOE (1981a)
- 19 Acceptance by special interest groups, public officials, and individual citizens may be crucial to the sites establishment. Its not necessary or even feasible that everyone support the process, but their understanding of the need for the site and the legitimacy of the site location process is required. USDOE (1981a)
- 20 Some possible tools for citizen participation are: citizen advisory committees, workshops, informal materials (newsletters, brochures, media interviews), project field offices (to service requests for information), and meetings, forums, and hearings. USDOE (1981a)

- 21 The lack of comprehensive [waste] classification system would hinder formation of interstate compacts, thus impeding development of regional disposal sites. USDOE (1981b)
- 22 In spite of the fact these [nuclear power-plant] wastes exist and have no place to go in the near future, solving this problem is tantamount to forcing acceptance of nuclear power in the minds of some people. USDOE (1981b)
- 23 The degree to which [disposal] alternatives can be implemented on a regional basis is important from the perspective of public acceptability. USDOE (1981b)
- 24 Disposal matched to the nature of the waste should be more acceptable than SLB because it implies a more rational approach than use of a single generic technique for a heterogeneous mix of materials and hazards. USDOE (1981b)
- 25 In disposal according to the nature of the waste, any components of the waste separated out as too hazardous for SLB will almost surely lead to disposal and public acceptance situations similar to those for HLW. It may then be appropriate to consign some LLW to HLW repositories. USDOE (1981b)
- 26 Codes of practice, supplemented by performance standards and measures of performance, would be useful for groups wishing to make independent evaluations of the performance of burial ground practices. Jacobs et al. (1980)
- 27 Public acceptance is a major concern: Acceptability of risk; Compatibility of low-level radioactive waste disposal with criteria for disposal of other hazardous wastes. Consistent formulation and assessment of risks from radiation. Comparison of risks from other energy source wastes. Macbeth et al. (1979)
- 28 Public acceptance, major concerns: Perception of risk versus hazards; Adequate information and understanding of risk assessment and cost-benefit tradeoffs. Definition of acceptable risks to public health and safety and the environment. Macbeth et al. (1979)
- 29 Public acceptance, major concerns: Ethical and moral issues; Morality of leaving "legacy" of concentrated hazardous wastes for future generations. Creditability of sources of information, especially in light of conflicting views among experts. Problem of appropriately transmitting descriptive information concerning waste disposal sites to future generations. Macbeth et al. (1979)
- 30 Both public acceptance and existing regulatory controls appear to be adequate for continuing present SLB practice. Macbeth et al. (1979)
- 31 Public opposition to new disposal sites comes primarily from nearby urban areas, not the rural areas in which disposal facilities would be located [and in which it is felt that] the growth potential outweighs environmental concerns. Macbeth et al. (1979)
- 32 To date there has been little information [provided] which would allow the public to make rational assessments of the risks associated with radioactive wastes [and to compare them] to other activities ensuing from modern technology. Macbeth et al. (1979)
- 33 The public as well as much of the scientific community appear inexperienced in assessing risks, [and, e.g.] in distinguishing [between] consequences and risks. Macbeth et al. (1979)
- 34 Because deeper burial provides greater isolation of the wastes from the human environment, and because of the possibility of using strip mines or other land unsuitable for more productive use, IDB may be more acceptable to the public than SLB. Macbeth et al. (1979)
- 35 Likelihood of future generations encountering the waste is less for IDB than for SLB, and hence public concern for moral and ethical questions should be reduced. Macbeth et al. (1979)
- 36 It is unclear as to how closely the weights assigned in the FBDU study to various evaluation factors pertaining to land disposal would match perceptions of importance in a broader sample of the population. The technical advisory panel polled to obtain the weights was not in close agreement, and moreover did not have members from all societal sectors. (e.g., no one from the NRDC was polled). Macbeth et al. (1979)
- 37 The EPA procedure for setting dose limits, applied to the setting of general standards, reduces the flexibility that can be applied by the using Agency and provides standards in which the outcome cannot be predicted before the standard is available. Thus, we find ourselves in the position of having no general guidance for the Agencies to follow so that they must wait until the more specific standard covering a proposed action is issued before they can take action or run risk of having action taken on the wrong basis. This has led to situations where individuals propose interim guidance at as low a level as they can conceive of (and often, perhaps, below a level at which the job can be done). The public believes that a standard of this nature represents a precipice between life and death. Thus, when the standards are exceeded, the public believes that they have been exposed to a dangerous situation and react accordingly. Healy (1980)
- 38 Major issues raised in public comments on DGEIS on uranium milling include: timing of regulations; application at existing sites; form of regulations; scope of GEIS; siting of mills; radon control and tailings cover requirements; period of long-term concern; groundwater protection; cost estimates; environmental impacts of obtaining reclamation cover material; financial surety; long-term funding; government land ownership and agreement state regulation. USNRC (1980a)
- 39 The public comments on the DGEIS milling were distributed as follows (topic (no. of comments)): scope (24); uranium demand and production (11); representativeness of models (28); analysis of base case impacts (231); alternatives evaluation (117); regulations (503); minor topics (54); and long-term isolation performance (47). Subtopics that elicited significant numbers of comments are as follows. USNRC (1980a)

- Base case impacts: radioactivity (releases, models, risk estimates) - 154;
atmospheric transport - 9; other nonradiological - 51.
Alternatives evaluation: definitions and selection - 45;
costs and cost-benefit - 47; long-term impacts - 23;
decision criteria - 30. The largest subtopics (e.g.,
applicability - 22, clarity - 26, basis and need - 35,
legal issues - 41, etc., received relatively fewer comments).
Some of the more conspicuous regulatory technical issues
were: above vs. below grade - 63; long-term funding - 48;
radon limit - 37; groundwater protection - 31; cover thick-
ness - 19; nonproliferation - 16 other - 26.
- 40 USNRC (1981a)
Section 20.311 of the proposed 10CFR20 amendments establishes
requirements for a manifest tracking system for wastes. [The
intended improvement of] the data base on waste should improve
the credibility of decision makers, enable better planning
for inspections and emergencies, enhance protection of the
future waste generation, and help in site specific analysis
and planning.
- 41 Murphy and Holter (1980)
It is assumed that a package in which waste is buried will
lose its integrity shortly after burial. Therefore, no credit
is taken for packaging of the waste.
- 42 Murphy and Holter (1980)
Relative effectiveness and impacts may be more important
than absolute values for comparative analysis of alternatives
but not for questions of acceptability, unless a "no action"
alternative is appropriately presented.
- 43 Valore and Larnar (1978)
No issues should be dismissed as a priori insignificant [in
environmental reviews]. [They] should be categorized and
addressed by a competent group, then accepted or dismissed in a
reasonable manner.
- 44 Hebert et al. (1978)
The technical community tends to accept risk estimates at
face value. In contrast, the general public often perceives
the outcomes of an event to be more important than the
probability. This may be due to the fact that the public
is familiar with Murphy's Law: If something can go wrong,
it will go wrong. Thus, probabilities are often
perceived to be less meaningful than outcomes.
However, it is not only the general public that considers
outcomes to be more important than probabilities in certain
situations. This often occurs in the world of business and
industry, and a good example is provided by the nuclear
area. Insurance companies would not insure nuclear reactors
for unlimited liability because they lack a data base for
actuarial calculations and because one large accident,
regardless of how improbable the accident was, could ruin
the insurance companies.
- 45 Cluett et al. (1979)
It is apparent that public concerns about the safety of
nuclear waste repositories, regardless of the extent to
which these concerns are based on an accurate understanding
of the risks involved, will be a critical impact of any
proposed waste management policy. In addition, giving the
public more information about radioactive wastes may not
eliminate critical risk assessments, since research has
found that increased knowledge can actually heighten people's
concerns about potential risks (Kasperson, et al., 1976).
- 46 Rotow et al. (1979)
As the attached NRDC Report shows, we believe a path
more responsive to EPA's legislated mandate and to public
perception is to approach waste management criteria from
a perspective that uses environmental non-degradation as
a fundamental goal.
- 47 Cochran et al. (1979)
Public confidence in any radioactive waste disposal system
will not be created by substituting mathematical modelling
exercises that are impossible to validate for objective
and verifiable design criteria. "Engineering judgement," that
is, best guesses of modelling assumptions, and model parameters,
should not be substituted for collecting basic scientific
data and conservatively applying these data. On the other
hand, by applying the philosophy of defense-in-depth, and
insuring that the test of each component against its
independent criteria can be validated with basic scientific
data, public confidence in waste disposal systems should
be improved. Management of uncertainty through application
of defense-in-depth is a better way to proceed than an
exclusive reliance on modelling.
- 48 National Acad. of Sci. (1979)
Waste disposal is often used as a basis for the political
expression of more generalized opposition to nuclear power
and to the whole decision-making mechanism for nuclear power.
- 49 National Acad. of Sci. (1979)
The whole matter has received a great deal of public attention
since about 1971, but little before. Present difficulties have
three main causes: the generally negligent and uncommunicative
attitude of the Atomic Energy Commission (AEC), even up to its
dissolution; continuing federal indecision about the accept-
ability of nuclear power; and an unfortunate mistaking of goals
for working policy. The management of radioactive waste has
been a political issue, which itself has several features.
The AEC was at the same time declaring the nuclear waste
problem to be tractable and straightforward, and was also
deluding itself that an abandoned salt mine in Lyons, Kansas,
originally selected only for nonradioactive experiments, was
ideally suited as a permanent repository, despite the
presence of solution mining in the same salt bed less than
2 miles away, and despite the many unrecorded drill holes
throughout the strata. When all these matters came to light,
the AEC and its successor agencies lost credibility that they
have not yet regained.
- 50 Farhar et al. (1980)
Public opinion data tend to focus on the "noneconomic"
factors influencing public preferences and action on
energy issues.
- 51 Farhar et al. (1980)
From local studies, it is found that heightened knowledge
[about the location of nuclear plants] leads to increase
community polarization over the issue.
- 52 Farhar et al. (1980)
The major problem perceived as associated with the nuclear
power are safety, environmental damage from radioactivity,
and waste disposal. These problems are considered serious
by large majorities, and the proportions indicating concern
have increased.
- A.4.6.1 Specific Examples of Expressed or Potential Concerns
- 1 USDOE (1981b)
Voters in one state recently passed an initiative to ban
the disposal of low-level nonmedical wastes from out of
state. This classification by source has national impact
on waste management practices.
- 2 USDOE (1981b)
[There] is the feeling that it is unfair for existing sites
to continue shouldering the entire national burden of LLW.

33 USDOE (1981b)

Frequent reports of discovery of abandoned, illegal dumps of hazardous chemical wastes and the fact that operational problems contributed to closing the Haxey Flats and West Valley sites have led to widespread demands that the regulatory framework be "tight" enough to ensure that high standards for safe disposal will be maintained.

4 Macbeth et al. (1979)

In combining injuries and fatalities to attain impact, fatalities were weighted ten times as heavily as injuries. (See Macbeth 1979, Table 3.2)

5 Macbeth et al. (1979)

Construction crew sizes, hence the worker population subject to occupational hazards, has been estimated by dividing estimated capital costs by a single factor for labor.

6 Macbeth et al. (1979)

Events such as the Three Mile Island incident tend to instill suspicion of all risk calculations, since to the public the fact that [it did] occur appears to make previous statements that it would be unlikely seem purposely misleading.

7 USNRC (1981a)

The public exposure limits proposed by the NRC are given as annual maximum doses, whereas a common view is that the hazard of an activity should be measured by the total dose commitment attributable to that activity.

8 Wilson (1978)

The Stark County Planning Commission of Stark County Illinois is opposed to the reopening of the Sheffield Dump Site, which is located in nearby Bureau County Illinois, and feels that it should be closed permanently. It will be our intent to suggest to the Stark County Zoning Board regulations forbidding the development of such dump sites in Stark County.

9 Wilson (1978)

The significant issues are: dump sites should not be located in heavily populated areas; should not be located in or near land which is used for crops or pasture; dump sites should be covered by more than 30 feet of earth due to percolation which occurs because of freezing and thawing; local opinion must be solicited if a dump is proposed to be located in a given area; and local zoning laws should be adhered to.

10 Valore and Lamarch (1978)

There should clearly be an exclusion zone around the facility, but a low population area is probably not necessary.

11 Doherty (1978)

He feels that it will be very important to have low level waste be removable in the event of events that make dispersal a possibility.

12 Shapiro (1981)

In 1966, downriver from a Durango tailings pile, the Anish carried three times the concentrations of radium 226 and strontium 90 permissible in drinking water. Even more alarming than these measurements were the levels of isotopes recorded in the cells of water organisms. The radium isotope was measured in river plants and creatures at up to ten thousand times its concentration in the river. This meant that as the radium was passed up the food chain from river plant to fish it became more concentrated, and thus more dangerous.

13 Shapiro (1981)

Last year, a retired Navy pilot told New Jersey environmental authorities that in 1947 he flew over the Atlantic three times and dropped a total of six tons of waste canisters, and that the flight records of these missions were later destroyed; similar accounts of unrecorded drops in the Pacific were later given to investigators for congressional committees.

14 Shapiro (1981)

In 1979, after Hurricane David, Louis G. Williams, an emeritus professor of ecology at the University of Alabama in Tuscaloosa, reported monitoring the passage of a "slug" of Tennessee River organisms contaminated by concentrations of cobalt six thousand times as high as normal fallout measurements and by concentrations of strontium and cesium eight thousand to ten thousand times as high.

15 Shapiro (1981)

For example, government trenches at the Hanford Reservation which contain sixteen million cubic feet of low-level solids are frequently burrowed into by desert animals, and when I visited there in 1979 I was shown (from a distance) a cage-brushed covered tract of about four square miles which had to be patrolled by health physicists, who vacuumed up radioactive droppings and the radioactive carcasses of rabbits, coyotes, and other creatures.

16 Shapiro (1981)

"So far during the lifetime of this site, we have never had waste sitting in water, and I think that is saying a lot." It may be saying too much. A 1978 Brookhaven National Laboratory survey found significant levels of radioactive cesium, cobalt, and manganese in water drawn from Burnwell trenches.

17 Shapiro (1981)

United States Geological Survey crew, digging [at Beatty] more than forty feet beyond a waste trench, punctured one of five waste drums that had been buried outside the disposal area's security fence.

18 Shapiro (1981)

By 1978, with more than three million cubic feet of material, Sheffield was filled to capacity. The facility could have expanded, but Nuclear Engineering's attempt to have adjoining land zoned was denied by the county Board of Supervisors, and, as at West Valley, the operator is now trying to turn the buried waste over to state control.

19 Shapiro (1981)

In 1976, Nuclear Engineering discovered and, to its credit, immediately reported that for some time several of its employees [at Beatty] had been diverting radioactive tools and materials from the burial site and selling them or giving them away. The EPA and the NRC then jointly conducted a radiological sweep of homes and ranches in and around Beatty. According to news reports, the contaminated items picked up and returned for burial at the site included scores of hand tools, sheets of plywood used in the construction of a playground, and a radioactive-materials shipping container that was being used as a livestock trough. It also turned out that a contaminated cement mixer borrowed from the repository which had become known in the region as "the store," had been used to lay down a radioactive floor at a local saloon.

- 20 The low-level and transuranic wastes that have built up in the equipment during its lifetime are inventoried as D & D material. ...Already classified as such are ... an estimated 19.4 million cubic feet of former Manhattan Project and AEC facilities that recent surveys have found to be contaminated to some degree.... Shapiro (1981)
- 21 The Oak Ridge annual survey for 1980 estimates that a program to clean up former Manhattan Project and AEC sites and one concentrating on Department of Energy surplus facilities that are being phased out will generate almost thirty million cubic feet of low-level waste-only slightly less than half the volume of all the low-level material that has been buried at federal sites since 1943-plus about three hundred and sixty-five thousand cubic feet of transuranic waste. Shapiro (1981)
- 22 In 1974, after searching through its records, the AEC said that it had been unable to find documentation of decontamination for seventy-three of a hundred and twenty-six such facilities once used by it or by the Manhattan Project. Eventually, twenty-six of these sites were found to be registering some of them more than a decade after decommissioning-radiation levels that the Energy Department says "appear to exceed rules for unrestricted release." Shapiro (1981)
- 23 One of the twenty-six sites originally given priority for possible remedial decontamination is the grave of the first nuclear wastes, beneath the clearing in Palos Hills. Tritium is still being monitored in wells there, but in lesser proportions than it was when I visited the site last year....The wells remain open, their old-fashioned mechanical pumps unmarked by warnings and accessible to anyone who might happen to pass by and draw up from underground streams the tritiated water that is one of the most persistent manifestations of a national legacy of more than three billion cubic feet of radwaste. Shapiro (1981)
- 24 The historical background on radiation standards presented above illustrates two aspects of the public's attitude toward radioactive contamination:
1. No amount of radioactive contamination is "acceptable." This was the public message that brought about the Atmospheric Test Ban Treaty and the demise of the Plowshare Program for the peaceful uses of nuclear explosives.
2. The effects of radiation on future generations are of prime importance and can not be discounted. This is illustrated not only by the ATB Treaty and Plowshare ban but also by the public concern over long lived nuclides and the tailing piles. Cochran et al. (1979)
- 25 EPA's attitude here is that a risk is acceptable to society if it exists and if nothing has been done about it: a simplistic attitude, since most risks in modern technological systems have never been explicitly reviewed for acceptability and are not well understood. In any event, very fundamental considerations show that the existence of a risk about which nothing has been done does not mean that the risk is acceptable to society. Rotow et al. (1979)
- 26 Because of the difficulty and cost of obtaining materials in such a remote location, the people of Beatty appeared reluctant to part with any item that could have a salvage value. Many residences were observed to have accumulated stockpiles of salvagable items including lumber, tires, automobiles, appliances, and a myriad of other materials. Plywood shipping containers were routinely disassembled to salvage the wood. Numerous radium dial objects, and contaminated tools of all kinds were diverted. It was apparent that any item of practical use or of just human interest had the potential for being diverted. Henslawski and Worth (1979)
- 27 The problem of disposal must be separated from the problem of spent fuel storage. National Acad. of Sci. (1979)
- 28 The quality of information circulated to the public about the nuclear waste problem can only be described as abysmal. Indeed, misinformation is rife. At one extreme, many nuclear proponents have claimed that the waste is less radioactive than the one after 500 years, a statement that is simply not true. At the other extreme, opponents have raised spectres of 250,000-yr hazards without a hint of their minute magnitude, or the minute consequences of such hazards. National Acad. of Sci. (1979)
- 29 Half the respondents to the Advance Notice offered a comment on ocean dumping and most were against it as an alternative for LLW disposal. The major perceived disadvantages are the probability of severe ecological damage, international repercussions, and the issue of dispersal versus containment. The only advantage seen by the respondents appeared to be the comparatively lower cost of disposal. USHRC (1981b)

A.5 FACILITY MANAGEMENT

- 1 Should a specific disposal site have a capacity rating for radioactivity which should not be exceeded? USEPA (1977b)
- 2 Should controls be implemented to prevent the use of low-level waste disposal sites for purposes other than those for which they were planned? Is it feasible to prevent relocation of such sites? Is this of major concern? For how long? USEPA (1977b)
- 3 In what manner should a low-level waste site be deactivated/decommissioned? How long after deactivation/decommissioning should surveillance be provided? USEPA (1977b)
- 4 Retrievability is not an issue that requires consideration for the burial of low-level naturally radioactive wastes. USEPA (1977b)
- 5 Public health, safety, and full-cost analysis are all essential components in the consideration of waste-disposal controls. USEPA (1978)
- 6 Interim storage onsite or offsite should be allowed while disposal capacity is being developed. Levin (1980)
- 7 It is essential that all aspects of the waste management be conducted with the fullest possible disclosure to and participation by the public and the technical community. USDOE (1980c)
- 8 Criteria establishing type and form (including packaging) of waste appropriate for burial, depth and dimensions of burial trenches, and capping are needed to ensure suitable operational practice. Deichman (1979)
- 9 Evaluations should be made of the potential hazard from contaminated objects that may be interesting or useful artifacts and procedures developed to provide security against their removal. Deichman (1979)
- 10 Interim storage would increase both occupational exposure and population risk. USDOE (1981b)
- 11 Technical issues related to problems experienced at existing shallow land burial facilities, which need to be resolved by further research and development in order to develop improved management practices and provide information for remedial actions at both closed and currently operating sites, may be grouped into seven major areas: (1) water management; (2) radionuclide migration; (3) waste inventory records; (4) performance monitoring and evaluation; (5) prediction capabilities; (6) space utilization; and (7) management practices. Jacobs et al. (1980)
- 12 Codes of practice, supplemented by performance standards and measures of performance, would be useful for groups wishing to make independent evaluations of the performance of burial ground practices. Jacobs et al. (1980)
- 13 A major need in shallow land burial of low-level radioactive wastes is a formal policy consisting of a written set of goals, objectives, criteria, performance standards, measures of performance, and codes of practice. Jacobs et al. (1980)
- 14 A specific item related to management practices that needs additional research and development emphasis is the technical evaluation of policy options. Jacobs et al. (1980)
- 15 Controls that we do not have now should be in place: for truckload shipments, quality assurance for packaging; a permit system for brokers to provide state inspection and control over users from that state; a uniform point system to monitor compliance; and power to levy fines. DiSibio (1980)
- 16 Repository operations must make adequate provisions for receipt of waste, waste handling and interim storage, on-site waste conditioning (if done at site), options for emplacement and utilization of engineered barriers, documentation of waste disposal, on-site monitoring, and enforcement of limits and constraints. IAEA (1981)
- 17 Repository operations must make adequate provisions for off-site surveillance to detect radionuclides that have been inadvertently released and ensure acceptable performance of the site for radionuclide containment. The monitoring should cover airborne radioactivity, waterborne radioactivity, and radioactivity in soil, vegetation and wildlife. IAEA (1981)
- 18 The principal parts of a disposal system which are readily identifiable and will be addressed in the minimum technical requirements are:
 - . Characteristics of the disposal site.
 - . Method by which the site is designed, the land disposal facility constructed, the waste emplaced, and the site closed.
 - . Degree and length of institutional control, surveillance and monitoring of the site after closure.USNRC (1981a)
- 19 The disposal site shall be used exclusively for the disposal of radioactive wastes. USNRC (1981a)
- 20 Facility operations and disposal site closure [requirements] for land disposal facilities other than near-surface [are reserved for future rulemaking]. USNRC (1981a)
- 21 Waste relocation involves the exhumation of buried waste, repackaging of the waste if necessary, and reburial of the waste at another disposal site or in another trench on the same site. Exhumation of waste originally buried without any intent of later retrieval is an expensive and time-consuming operation that has a potential for significant radiation exposure to decommissioning workers. Therefore, waste relocation would likely be considered only in situations where other decommissioning procedures are inadequate to ensure that future risk from the facility is within acceptable bounds. Murphy and Holter (1980)

- 22 Murphy and Holter (1980)
Decommissioning modes for SLB sites correspond to those for fuel cycle facilities as follows: waste relocation/dis-
mantlement, stabilization/encapsulation, and long-term care/
safe storage. Definitions of actions, facility status, and
land use category for these modes are given by Murphy and
Holter in Table 4.1-1.
- 23 Murphy and Holter (1980)
Safety analyses for decommissioning include radiological
and nonradiological hazards to the public and workers from
normal decommissioning operations and from postulated
accidents. The safety analyses utilize established data and
methodology to estimate the various factors required, such
as release mechanisms, dispersion pathways, and exposure
modes of the released materials.
- 24 Murphy and Holter (1980)
Estimated time required to relocate the waste from an entire
reference burial ground range from 20 to 25 years.
- 25 Murphy and Holter (1980)
As shown in Table 13.4-2, the option of relocating an entire
trench offsite could result in two to three nonradiological
injuries. For no cases would a fatal injury be expected, and
for the other options even the probability of nonfatal injury
is slight. However, relocating 100,000 to 200,000 cubic meters
offsite (truck transport assumed), about 12 to 24 reference
site trenches, would carry an expectation of from one to
three fatalities.
- 26 Cochran et al. (1979)
The waste repository design criteria should reflect NRC's
strong historical emphasis on the single failure criterion;
accordingly, their development should proceed under the
defense-in-depth philosophy. Thus, the process should begin
by resolving the proposed waste disposal plan into a few
carefully chosen parts, each of which can be regarded as an
independent component. The keystone of this proposed
licensing process is that each component of the waste
management plan must be sufficient to duplicate the isolation
performance of the natural state (reference ore body) even if
all other parts of the waste management system are arbit-
rarily assumed to have failed to perform.
- 27 National Acad. of Sci. (1979)
The problem of disposal must be separated from the problem
of spent fuel storage.
- 28 Lester et al. (1981)
Any pre-burial storage not on the actual burial site is
considered part of packaging. Interim storage at the burial
site (including parked trucks) is considered as part of the
burial operation. Transportation begins and ends at the
boundary between public roads and private roads at the
packaging/collection or burial location. Therefore, loading
and unloading are not considered to be transportation op-
erations. Packaging and transportation will be considered non-
site-specific as it is possible to do a reasonable generic
analysis based on a national system. Therefore, only one set
of pathways will be described for transportation and for
packaging.
The pathways associated with burial operations and subsequent
site activities can be highly site-specific. Therefore, in
the following sections separate pathways are presented for
each existing site and for reference sites.
In each aspect of the shallow land burial system there is a
potential for release of radionuclide material to the popula-
tion. Such release can occur through a number of mechanisms
many of which are very improbable. The system has been divided
into five parts for the purpose of pathways analysis:
(1) packaging, (2) transportation, (3) burial operations,
(4) administrated post-closure, and (5) limited public use.
- 29 Lester et al. (1981)
LLW release scenarios were developed by specifying the waste
management activity phase, the initiating events, package types
properties of the waste, vehicle condition, source category
of the waste, and entry pathways. Activity phases are:
packaging, transportation, unloading (arrival, handling),
burial (placement, uncovered wastes, backfill), repackaging,
post-burial (administrative control, limited public use).
Initiating events are chronic (direct radiation, atmospheric
release, site contamination), natural events (rain/flood/wind),
operational (container rupture, waste spill, fire, or explosion),
and intrusion events (theft, animals). Waste properties
include solubility and wind dispersibility. Source categories
include decommissioning waste and heterogeneous. The entry
pathways are: aquifer, atmospheric, direct radiation, erosion,
contamination spreading, and unsaturated zone flow.

A.5.1 Monitoring Goals and Programs

- 1 Groundwater monitoring-procedure design must
consider sample collection procedures. USEPA (1981d)
- 2 Groundwater monitoring-procedure design must
consider sample preservation and shipment
procedures. USEPA (1981d)
- 3 Groundwater monitoring-procedure design must
consider analytical methods. USEPA (1981d)
- 4 Groundwater monitoring-procedure design must
consider the chain of sample-custody control. USEPA (1981d)
- 5 Development of standard methods for measuring
distribution of radionuclides in soil [is desirable]. Levin (1980)
- 6 Independent monitoring by DOE-ASEV will be conducted
during the remedial action and periodic status reports
will be prepared. USDOE (1980b)
- 7 The effectiveness of a monitoring system largely depends
on the knowledge of a sites geology and hydrology,
[e.g. sc] that sampling points are properly placed in
relation to possible paths of migration. [GAD, 1976] Lipton (1981)
- 8 A Dames and Moore report emphasizes the use of
hydrogeological modeling to determine cost-effective
placement of monitoring wells. Lipton (1981)
- 9 A minimum preoperational radiological surveillance
program [would be]:
(1) Establish natural background radiation for the
[actual] disposal area, the buffer zone, and the
area outside the buffer zone.
(2) Gamma doses measurements from meteorological and
for hydrogeological sources.

- (3) In-situ quantitative gamma spectrometric measurements, and analysis to apportion the total gamma rate among the contributing radionuclides.
- (4) Air samples for gross beta, and gamma isotopic. (monthly composites).
- (5) Periodic gamma isotopic analysis of water, and biota per site specification. Particular attention should be given to critical pathways and sampling for seasonal variations.
- (6) Baseline data should be obtained on x-emitters, such as Ra-226, Pu-238, Pu-239, and Th-232.
- 10 The numbers and placement of monitoring devices should be based both on available information on potential migration pathways and on cost-benefit considerations. Lipton (1981)
- 11 Future monitoring programs must
(a) verify compliance with accepted standards
(2) identify potential problems in time to prevent any adverse public impact, and
(3) provide public assurance of the safety of SLB. Lipton (1981)
- 12 Development of methodology and equipment for monitoring burial sites (is a priority technical issue). Deichman (1979)
- 13 The monitoring program at shallow land burial sites needs to be improved by placing ground-water monitoring wells at optimum locations, and designing the system so that other waste management activities do not mask evaluation of the contribution of the burial grounds to the overall release from the facility. The monitoring program should satisfy the generally accepted objectives and requirements of environmental monitoring around nuclear installations. Jacobs et al. (1980)
- 14 An assessment should be made of techniques and instruments currently in use and those being developed for monitoring. The assessment would serve as a guide establishing additional monitoring research needs. Particular attention should be given to measurement accuracy and to in situ devices capable of continuous measurement. Jacobs et al. (1980)
- 15 Sampling should be conducted at selected disposal sites to identify and quantify the soil microorganisms present. Laboratory studies should be conducted using soil materials and trench leachates from selected sites inoculated with typical soil microorganisms to identify the reaction mechanisms of microorganisms with radionuclides. Products of microbial interaction with the wastes should be identified to evaluate the potential effects on radionuclide migration and bioavailability. Deichman (1980)
- 16 Monitoring of parameters directly affecting water migration (the principal agent for transport of radionuclides within and from burial sites) and radionuclide migration should be conducted. Criteria and performance standards should be developed so that predetermined remedial action measures are implemented when "trigger" levels are reached. Improved monitoring techniques and instruments should be developed and demonstrated and efforts continued to further upgrade monitoring systems. Attention should be given to development of statistically sound programs for operational and postoperational monitoring systems. Deichman (1980)

- 17 While the primary means of isolating mill tailings must be physical barriers, it would be prudent to have some continued surveillance and control of land uses at tailings sites to confirm that there is no disruption by either natural erosion or by human-related activities, as a supplementary measure. USMRC (1980a)
- 18 Preoperational monitoring shall provide basic environmental data on ecology, meteorology, climate, hydrology, geology, and seismology of the site data for site characteristics subject to seasonal variation must cover at least a twelve month period. USMRC (1981a)
- 19 Postoperational surveillance must include a monitoring system capable of giving early warning of migration of radionuclides from the site and plans for corrective measures should the performance objectives appear to be jeopardized. USMRC (1981a)
- 20 Program objectives for environmental surveillance and records maintenance include:
• detection of changes in and evaluation of long-term trends of concentrations of radionuclides in the environment, with the intent to detect radionuclide migration and initiate appropriate actions
• collection of data on the history of contaminants released to the environment, with the intent of discovering previously unconsidered pathways and modes of exposure. Murphy and Holter (1980)
- 21 Because site stabilization or waste relocation activities may disrupt site edaphic conditions and vegetation, additions and/or changes in environmental monitoring as compared to the operational monitoring program may be required (e.g., in onsite soil, air, and vegetation sampling). Murphy and Holter (1980)
- 22 Core sampling to verify or determine content of a trench might have an initial series of borings on approximately 5-m spacings, in 3 rows, made over the length of the trench resulting in about 90 cores. Allowing an additional 25 holes for areas that appear to warrant more precise characterization, a total of 115 cores might be assumed for characterization of a trench. Murphy and Holter (1980)

A.5.2 Water Management Goals and Programs

- 1 Water management difficulties could pose a long-term operational problem for the closed Maxey Flats site. USDOE (1981b)
- 2 The most serious technical problems in shallow land burial are related to water management. Water provides a primary vehicle both for erosional processes, which can reduce the structural integrity of waste trenches and the trench caps and for migration of the radionuclides. Radionuclide migration in water and subsequent possible exposure to the public, begins with entry of water into the burial trench. The most common ways water comes into contact with the waste are from infiltration of precipitation through the trench caps and/or walls or from erosion leading to exposure of the buried waste. Jacobs et al. (1980)

3 At locations such as at ORNL, Maxey Flats, and West Valley where the climate is humid and the permeability of the backfill is greater than that of the undisturbed formation, periodic sealing may be required to limit infiltration of water. Jacobs et al. (1980)

4 Both infiltration and erosion can be controlled by water management practices. Erosion control practices include a good vegetative cover, a permeable cap, and shallow slopes; whereas measures for infiltration control include limiting vegetation, an impervious cap, and a high slope to promote rapid drainage. Hence, management practices that reduce erosion may enhance infiltration, and vice-versa. Selection of a suitable burial site management program must consider a balance between the control of infiltration and erosion. Jacobs et al. (1980)

5 The control of infiltration of water into trenches is a major step in the prevention or minimization of contact between water and buried waste. Studies have identified many of the factors that control water infiltration, and have led to suggestions for practices for reducing it. Most of the factors and mitigating practices relate to cap and trench design. Pumping accomplishes the greatest reduction in trench water, but it is by far the least cost-effective and should be considered a favorable management option only on a short-term basis. Jacobs et al. (1980)

6 A comprehensive evaluation of water management to control infiltration is needed. A literature review should be made of field experience at both radioactive and nonradioactive burial facilities. Much of the experience at operational facilities may not be reported in the literature; thus, interviews or questionnaires may be necessary to retrieve the desired information. The findings should be used to identify techniques that have technical promise or which have been useful at specific sites. These techniques should then be subjected to experimental examination in field situations with particular attention given to imposing both controlled conditions to enable intercomparison of techniques and ranges of anticipated conditions at sites of potential application. The anticipated conditions should include not only the native hydrogeological characteristics of the site, but also the changes in parameters that may occur from operation of the facility or from nearby construction. Jacobs et al. (1980)

7 The adoption of optimum practices of control of infiltration at a burial site may be at cross practices with optimum erosion control. Good water management practice must consider the effects of possible practices on both infiltration and erosion and arrive at the policy best suited for optimum water management at the site. This balance will likely vary from site to site, reflecting differences in hydrology, climate, topography, soil mechanics, geology, etc. Jacobs et al. (1980)

8 Specific items related to water management that need additional research and development emphasis include: (1) field testing and engineering evaluation of techniques for control of infiltration and erosion; and (2) development of a rationale for arriving at a balance between control of infiltration and erosion. Jacobs et al. (1980)

9 Steps shall be taken to reduce seepage of toxic materials into groundwater, including consideration of installation of low permeability bottom liners. When clay liners or thin in situ clay soils are to be relied upon, tests shall be run long enough to reveal any effects which may occur (deterioration has been observed to occur rather rapidly after about 9 months of exposure, in some cases). USMRC (1980b)

10 At several disposal sites, trench caps have failed due to the formation of voids as the waste and waste packages deteriorate and then compact. Failure of the trench cap allows excessive infiltration of precipitation and destroys the effectiveness of any bicobarrier that may have been installed, resulting in increased rates of radionuclide migration and a safety hazard to operations staff. These failures could be prevented or ameliorated by compacting the waste in situ to reduce void volumes, improving the cap strength, providing better structural support for the cap, or using standardized modular containers containing compacted waste which permit compact stacking. Deichman (1980)

A.5.3 Records, Documentation, and Reporting

1 Disposal site owner/operator should provide a description of the specific hazardous wastes to be disposed of in the facility and the expected rate of deposition. USEPA (1980c)

2 Disposal site owner/operator should provide a description of any in-situ process that is expected to occur in the facility. USEPA (1980c)

3 Disposal site owner/operator should provide a description of the rate of mass transport of leachate from the disposal facility. USEPA (1980c)

4 Disposal site owner/operator should provide a description of the earth materials above the zone of saturation through which the leachate released from the facility will migrate. USEPA (1980c)

5 Disposal site owner/operator should provide a description of the earth materials in the saturated zone in which the leachate released from the land disposal facility will migrate. USEPA (1980c)

6 Disposal site owner/operator should provide a description of the hydrogeology of the area surrounding the facility. USEPA (1980c)

7 Disposal site owner/operator should provide a description of the discharges (into surface water) and withdrawals of groundwater that will be mixed with leachate from the disposal facility. USEPA (1980c)

8 Disposal site owner/operator should provide a description of the use of all surface water and groundwater that comes in contact with the projected leachate plume from disposed wastes. USEPA (1980c)

- 9 A final report [on each] remedial action and all supporting documentation will be stored in Federal Archives, and copies or summaries placed in records of appropriate local and state agencies. USDCE (1980b)
- 10 Documentation of burial practices: An encyclopedia of recommended practices and procedures for SLB, based on effectiveness of practices used in past operations, would be a cost-effective means of improving SLB. Extensive site examination composed of literature reviews, interviews with past and present operational personnel, working tours at facilities, and access to non-published records would be required [to compile the encyclopedia]. Deichman (1979)
- 11 Records on waste receipts and burial ground operations for the early years of operation of the contractor facilities are generally poor. Relatively little is known about the identity, quantity, and concentration of contaminants associated with these wastes. Many records contain only general information on the form, composition, or isotopic content of the waste. Records maintenance has been recognized as a problem at several existing major burial sites. Jacobs et al. (1980)
- 12 Guidance is also needed by the site operators for dealing with waste receipts that do not meet the criteria for transport or disposal. Jacobs et al. (1980)
- 13 Specific items related to waste records that need additional research and development emphasis include: (1) standardization of records; (2) verification of waste receipts; (3) development and appreciation of techniques to construct inventories from past operations. Jacobs et al. (1980)
- 14 Present records frequently provide insufficient information about the radiological, physical and chemical characteristics of waste package contents received for burial to permit prediction of the long-term behavior of the waste in burial grounds. Improved instrumentation and measurement techniques are needed to provide the disposal site operator with the capability of verifying that the contents of the waste package conform to the properties required to be listed on standard burial forms. Deichman (1980)
- 15 Section 20.311 of the proposed 10CFR20 amendments establishes requirements for a manifest tracking system for wastes. [The intended improvement of] the data base on waste should improve the credibility of decision makers, enable better planning for inspections and emergencies, enhance protection of the future waste generation, and help in site specific analysis and planning. USNRC (1981a)
- 16 [Closure application must include] results of any tests, experiments, or analysis pertinent to long-term containment, e.g., on backfill, waste migration and interaction with the site. USNRC (1981a)
- 17 [Closure applications must include] any proposed revision of plans for decontamination &/or dismantling facilities, backfilling, stabilization of the site. USNRC (1981a)
- 18 Program objectives for environmental surveillance and records maintenance include:
 . detection of changes in and evaluation of long-term trends of concentrations of radionuclides in the environment, with the intent to detect radionuclide migration and initiate appropriate actions
 . collection of data on the history of contaminants released to the environment, with the intent of discovering previously unconsidered pathways and modes of exposure. Murphy and Holter (1980)
- #### A.5.4 Performance Evaluation, Quality Assurance
- 1 Groundwater monitoring-procedure design must include an appropriate monitoring program for non-compliant periods of facility operation. USEPA (1981d)
- 2 A quality assurance program must be implemented to identify and minimize errors in the environmental monitoring program, including those due to:
 (1) Nonuniformity of the sample population.
 (2) Limited sample size, sample points, and collection frequency.
 (3) Analytical errors due to storage, preparation, and aliquoting variabilities; instrumental variabilities; and counting statistics.
 (4) Variability in data treatment and interpretation. Lipton (1981)
- 3 Development of instrumentation to verify waste receipts [is a priority issue.] Deichman (1979)
- 4 Criteria and performance standards should be developed so that predetermined remedial action measures are implemented when "trigger" levels are reached. Deichman (1979)
- 5 Performance evaluation requires an integrated assessment of (1) preoperational, operational, and post-operational characteristics and practices; (2) a complex system of procedures (site engineering, stabilization, and maintenance; trench construction; waste receiving, segregation, emplacement); and (3) interactions of procedures with site characteristics (meteorologic, geohydrologic, biologic). Deichman (1979)
- 6 There are two major needs in the area of performance evaluation for burial ground operations: (1) A well-defined set of goals, criteria, and performance standards and (2) monitoring programs designed specifically to monitor burial ground operation for those factors included in the performance standards. Jacobs et al. (1980)
- 7 Performance evaluation of burial ground facilities requires a carefully monitoring system, the establishment of criteria for evaluation, and the development of technology for monitoring. Jacobs et al. (1980)

- 8 Guidance needs to be developed and provided to the site operator for the design of a suitable monitoring system for performance evaluation. The guidance should have three major considerations. First, the important pathways of radionuclide movement must be identified. Second, measurement locations must be established which will facilitate the detection and characterization of radionuclide movement. Third, measurement must be statistically sound for accurate depiction of radionuclide movement and the consequences. Jacobs et al. (1980)
- 9 Unlike the monitoring for releases of radionuclides from a site, monitoring to evaluate performance requires that measurements be made at locations in addition to the perimeter. A monitoring network for performance evaluation should reflect the anticipated major pathways of migration as determined above, and should collect information to represent the spatial and temporal distribution of radionuclides. Jacobs et al. (1980)
- 10 The development of a suitable program for monitoring performance evaluation is an iterative process. The system cannot be designed until sufficient information is available to predict the significant pathways and rates of radionuclide migration. Measurement points should be clustered around these significant pathways and as further information becomes available from the monitoring programs, the design of the system should be modified. Jacobs et al. (1980)
- 11 Standards and measures of performance against which to evaluate the acceptability of burial ground performance are needed. Until environmental protection standards and limits of release specific to shallow land burial have been established by EPA and NRC, assistance should be given each facility in the development of performance standards for their operations. The development of specific site performance standards should be coupled with the establishment of remedial actions to be implemented when "trigger" levels are reached. The establishment of remedial action plans for each site would be an important step in gaining public confidence in burial operations. A well-developed set of performance standards, measures of performance, and graded action levels would also facilitate review of the acceptability to the public of facility operations. Jacobs et al. (1980)
- 12 At sites where there has been no detectable migration of radionuclides, the problems that have occurred have resulted largely from lapses in good management practice. There is a need to establish codes of practice to facilitate quality control for management practices at operating facilities. The codes should cover all aspects of facility operation, e.g., waste handling, emplacement, records, monitoring and site closure. Jacobs et al. (1980)
- 13 Specific items related to performance evaluation that need additional research and development emphasis include: (1) Development of site-specific models of radionuclide migration to serve as a basis for design of monitoring programs; (2) development of criteria, performance standards, and measures of performance; and (3) improved monitoring inside the perimeter of the burial ground. Jacobs et al. (1980)

A.5.5 Closure, Stabilization, and Long-Term Care

- 1 Landfill-closure design and post-closure care must consider the type and amount of waste in the facility. USEPA (1981d)
- 2 Landfill-closure design and post-closure care must consider the mobility and expected rate of migration of the disposed waste. USEPA (1981d)
- 3 Landfill-closure design and post-closure care must consider site location topography and surrounding land use. USEPA (1981d)
- 4 Landfill-closure design and post-closure care must consider climatic conditions in the area. USEPA (1981d)
- 5 Landfill-closure design and post-closure care must consider characteristics of the cover including material, final surface contours, thickness, porosity, and permeability, slope, length of run of slope, and type of vegetation on the cover. USEPA (1981d)
- 6 Landfill-closure design and post-closure care must consider geological and soil profiles and surface and subsurface hydrology of the site. USEPA (1981d)
- 7 Post-closure care design must consider the maintenance of any groundwater monitoring system. USEPA (1981d)
- 8 Development of operational practices to minimize reliance on post-operational control and surveillance [is a priority technical issue]. Deichman (1979)
- 9 The final disposition of tailings or wastes at milling sites should be such that ongoing maintenances is not necessary to preserve isolation. USMRC (1980b)
- 10 Suitable operational practices should be developed and demonstrated for use during the active operational stages of the site that will minimize the postoperational time period that continued control and surveillance will be required. These practices should be designed to ensure that buried waste is protected from erosion, leaching, infiltration, biological cycling, and intrusion and/or exhumation until radiation levels have decayed to non-toxic levels. Criteria establishing the type and form of waste (including packaging) appropriate for burial, depths and dimensions of burial trenches, and trench capping are needed to assure operational practice. Deichman (1980)
- 11 Shutdown and surveillance of repositories should make appropriate provisions for stabilization, near-term surveillance, maintenance and access control, at appropriate levels during a demonstration period and period of administrative control. At the end of the administrative control period, after verification that the radioactivity of the waste has reached a level compatible with no radiation protection requirements, restrictions on the use of the site could be lifted. IAEA (1981)

- 12 USHRC (1980a)
While the primary means of isolating mill tailings must be physical barriers, it would be prudent to have some continued surveillance and control of land uses at tailings sites to confirm that there is no disruption by either natural erosion or by human-related activities, as a supplementary measure.
- 13 USEPA (1980d)
The standards require a reasonable expectation that the disposal methods will be effective for at least one thousand years.
- 14 USHRC (1981a)
Safety over the long term involves (1) protection of individuals from inadvertent intrusion and contact with the waste in the future, (2) protection of the general public from potential releases to the environment, and (3) stability of the disposed wastes and the site to eliminate need for ongoing maintenance after closure.
- 15 USHRC (1981a)
HRC has received evidence of a great deal of public interest concerning the issue of financial responsibility for closure of a disposal site, through both numerous written comments on the preliminary draft regulation and the four regional workshops held to review it.
- 16 USHRC (1981a)
The postclosure observation and maintenance period is expected to last about five years to assure that the disposal site is in stable condition so that only minor custodial care, surveillance, and monitoring by the custodial agency are required.
- 17 USHRC (1981a)
Active maintenance means any significant remedial activity needed during the period of institutional control to assure that performance objectives are met; it does not include [routine] custodial activities or minor repairs.
- 18 USHRC (1981a)
Institutional control periods of up to 100 years permit the disposal of Class A segregated and Class B stable waste without special provisions for intrusion protection, since these wastes will decay during the 100 year period to levels that do not pose a danger to public health and safety.
- 19 USHRC (1981a)
Class C waste must be buried deeper than other waste, or, if site conditions prevent this, protected by engineering barriers. The assured effective life of these barriers is 500 years, and the maximum radionuclide concentration for all wastes must, in general, be such that at the end of the 500 year period no danger to public health and safety remains.
- 20 USHRC (1981a)
The licensee must remain at the disposal site [after closure] for a period of at least five years, for post-closure observation and maintenance to assure that the site is stable and ready for institutional control.
- 21 USHRC (1981a)
Analysis [in license applications] of long-term stability and of need for postclosure maintenance must rest on analysis of active natural processes such as erosion-mass wasting, slope failure, and adjacent soils, and surface drainage.
- 22 USHRC (1981a)
[Closure applications must include] any significant new information on the environmental impact of closure activities and on long-term performance of the site.
- 23 USHRC (1981a)
Site design must be directed toward long-term isolation and avoidance of active maintenance.
- 24 USHRC (1981a)
Site design and operation must be compatible with [an adequate] site closure and stabilization plan.
- 25 USHRC (1981a)
Adequate closure and stabilization measures must be carried out as each disposal unit (e.g., each trench) is filled and covered.
- 26 USHRC (1981a)
An applicant for license must provide, prior to commencement of operations, assurance that sufficient funds will be available for the disposal site closure and stabilization, including decontamination or dismantling facility structures, and such operations or activities as are needed to ensure that no active maintenance will be needed during the postclosure period.
- 27 Murphy and Holter (1980)
Site/waste stabilization plans are summarized by Murphy & Holter in Table 2.8-1 for an arid western site and a humid eastern site. Principal actions are listed for minimal, modest, and complex plans.
- 28 Murphy and Holter (1980)
Long-term care includes administrative control, environmental surveillance, and site maintenance. Administrative control includes:
 - control site access
 - coordination of surveillance and maintenance activities.
 - control of land-use and property-development activities.
 - performance of necessary records maintenance
Environmental surveillance includes:
 - collection of environmental samples
 - analysis of environmental samples
 - records maintenance
Site maintenance includes:
 - maintenance and repair of fences, gates, monitoring systems, etc.
 - erosion control
 - trench cap repair
 - water infiltration control
 - vegetation management.
- 29 Murphy and Holter (1980)
Stabilization procedures would normally be included as part of burial ground operations. For sites where adequate site/waste stabilization has not been performed during the operating phase, these activities would be performed at the conclusion of burial operations prior to termination of the operating license.
- 30 USDOE (1981d)
When Bear Creek was approved, developers needed only the mineral rights to land in order to bury uranium mill tailings. Now, under the Uranium Mill Tailings Radiation Control Act of 1978, they must either control title to the surface on which they deposit their tailings, or construct their disposal facilities on land controlled by a government entity. In Bear Creek's case, the surface of the tailings site is controlled primarily by the State of Wyoming and to a lesser extent by the U.S. Forest Service. Following reclamation of the tailings area and termination of the Bear Creek Project, title will either be retained by these entities or wholly transferred to the federal government.

- 31 In 1975, pursuant to state and federal regulations, the Bear Creek Uranium Co. submitted a plan to reclaim and revegetate disturbed lands continuously throughout the life of the project. Topsoil removed from each mined area is segregated from overburden, and is either stockpiled or placed directly on graded and contoured areas. The company grades all waste dump and pit backfill areas to blend with adjacent topography and to provide a positive drainage for runoff. It will also leave a portion of one pit and all of another as water impoundments for livestock and wildlife use, and as a potential irrigation source for local ranches. After milling operations shut down, the tailings will be covered with 10-16 feet of overburden whose surface will be compatible with the natural land. Six inches of topsoil will be applied, seeded, and mulched. Fencing will keep people and livestock away from the reclaimed tailings area until Wyoming's Department of Environmental Quality finds surface radiation levels safe for unrestricted grazing. Visual surveillance of the site will continue over the long term. Finally, ranch owners have negotiated individually with the company regarding financial and other compensations for the loss of their grazing land. The company seeks to minimize its impacts on water supplies by providing water to ranches from other sources.

A.5.6 Historical Problems-Examples

- 1 Because disposal operation have modified the hydrogeological characteristics of the West Valley site, erosion control and water management could pose major long-term problems.
- 2 Technical problems at the three closed [disposal] sites fall into four categories:
1. Site-specific: mainly water control.
 2. Waste-specific: identification, form, migration modes.
 3. Operation-specific: trench-structure management, security.
 4. Performance-specific: including monitoring, performance standards.
- 3 SLB has been safely practiced for over 30 years at government sites and for nearly 20 years at commercial disposal sites, and in no instance has concentration of radionuclides even approached regulatory standards.
- 4 The actual burial rate at Maxey Flats (measured in Ci) exceeded the preliminary assured burial rate by a factor of 30. This experience points to the need for realistic planning estimates and for careful monitoring and control during operation.
- 5 Water has come into contact with waste in burial trenches at six of the eleven major land burial facilities. (Solutions for some of these water problems have been implemented or proposed.)
- 6 The backfill material covering trenches has sagged and collapsed in some trenches at ORNL and Maxey Flats. Sagging of trench covers can enhance the infiltration of water into the trenches.

- 7 Trench caps have eroded at Maxey Flats, West Valley, LAGL, and ORNL and periodic maintenance is required. It has been suggested that high velocity winds at burial sites in arid climates might result in removal of significant amounts of trench cover.
- 8 In November 1973, Kentucky instituted a special six-month environmental monitoring study to identify the source and scope of increased levels of environmental radioactivity in the Maxey Flats site environs. The study report concluded that the burial ground was contributing radioactivity to the local environment; that the activity detected did not create a public health hazard.
- 9 In 1972, a test excavation was made in a burial trench at the Savannah River Laboratory that had been filled in 1958. The waste articles were in exceptionally well-preserved condition. Radioactivity levels encountered at the excavation were essentially at normal area background.
- 10 A second waste retrieval program at INEL, the Early Waste Retrieval project was initiated in FY 1976 to investigate the problems associated with retrieval and repackaging of drummed and boxed TRU waste material that was buried between 1960 and 1963. The waste material and drums were found to be randomly distributed in the trenches. Virtually all the waste drums were severely rusted and otherwise badly deteriorated. Several of the drums contained liquids. In some cases, the liquids leaked from the drums during excavation. In all cases, the spread of contamination was confined within the OAC building.
- 11 United States Geological Survey crew, digging [at Beatty] more than forty feet beyond a waste trench, punctured one of five waste drums that had been buried outside the disposal area's security fence.
- 12 In 1976, Nuclear Engineering discovered and, to its credit, immediately reported that for some time several of its employees [at Beatty] had been diverting radioactive tools and materials from the burial site and selling them or giving them away. The EPA and the NRC then jointly conducted a radiological sweep of homes and ranches in and around Beatty. According to news reports, the contaminated items picked up and returned for burial at the site included scores of hand tools, sheets of plywood used in the construction of a playground, and a radioactive-materials shipping container that was being used as a livestock trough. It also turned out that a contaminated cement mixer borrowed from the repository which had become known in the region as "the store," had been used to lay down a radioactive floor at a local saloon.
- 13 In 1974, after searching through its records, the AEC said that it had been unable to find documentation of decontamination for seventy-three of a hundred and twenty-six such facilities once used by it or by the Manhattan Project. Eventually, twenty-six of these sites were found to be registering some of them more than a decade after decontamination-radiation levels that the Energy Department says "appear to exceed rules for unrestricted release."

14

Shapiro (1981)

One of the twenty-six sites originally given priority for possible remedial decontamination is the grave of the first nuclear wastes, beneath the clearing in Palos Hills. Tritium is still being monitored in wells there, but in lesser proportions than it was when I visited the site last year....The wells remain open, their old-fashioned mechanical pumps unmarked by warnings and accessible to anyone who might happen to pass by and draw up from underground streams the tritiated water that is one of the most persistent manifestations of a national legacy of more than three billion cubic feet of radwaste.

15

Henslawski and North (1979)

Because of the difficulty and cost of obtaining materials in such a remote location, the people of Deatty appeared reluctant to part with any item that could have a salvage value. Many residences were observed to have accumulated stockpiles of salvageable items including lumber, tires, automobiles, appliances, and a myriad of other materials. Plywood shipping containers were routinely disassembled to salvage the wood. Numerous radium dial objects, and contaminated tools of all kinds were diverted. It was apparent that any item of practical use or of just human interest had the potential for being diverted.

16

USDCE (1981d)

During the operation of the Climax Uranium Company's Grand Junction mill, some 1.9 million tons of tailings were produced, most of which remain on the site. The most likely remedial action plan involves the removal of the tailings from the current site which is adjacent to densely populated areas to a more remote site for deeper burial. Beginning in 1952, the company began to give away the tailings to local contractors, who were requesting them for use for building material. It is estimated that well over 50,000 tons of the tailings were used in the building of various structures, while some 250,000 tons were used in the construction of local streets, driveways, swimming pools, and sewer lines. In the late 1960's it was found that tailings used in this manner were potentially dangerous to public health, and an extensive investigation began. What had appeared to be a solution to the mill tailings disposal problem developed into a serious environmental and public health problem. Federal funds have been authorized to clean up part of the problem at Grand Junction (with additional financial support to come from matching State funds to clean up areas in the country where radiation levels exceed guideline levels). As investigations have proceeded, the estimated number of affected homes and other structures has increased from 100 to over 800. In 1979, the Department of Energy estimated that the remedial program would cost approximately \$17 million.

17

USDCE (1981d)

Because archaeological sites were suspected in the area, Plains Electric began working closely with the State Historic Preservation Officer early in the planning stages. Results of preliminary surveys indicated those areas where presence of archaeological resources was most probable. Plains Electric, Rural Electrification Administration, the New Mexico State Historic Preservation Officer, and members of the Advisory Council for Historic Preservation consulted and prepared a Memorandum of Agreement which outlines the course that Plains Electric will follow to migrate the impacts to the resources. By planning in advance and by developing

a well-thought-out mitigation strategy, Plains Electric has found that the construction schedule will not be disrupted. They have also found that by coordinating frequently and openly with the scientific community and the State Historic Preservation Officer, consultation and decisions on mitigation strategies are accomplished quickly.

18

USDCE (1981d)

A more serious problem arose because various Indian groups declared that sacred burial grounds and cultural resources existed in the area. They insisted that these sites could not be touched under any condition. Unfortunately, not only would the trenching activities impact on these sites, but these sites are often times disturbed by the archaeologists engaged in data recovery operations. The problem with the Indian cultural sites was unmitigable because the Indians demanded that the site not be touched. Because the seismic study required extensive trenching activity, impacts were inevitable. Since there are no regulations governing these types of problems the battle had to be fought in the courts. The LNG Terminal Associates won, but at the expense of delays to the seismic studies. There was also some problem with acquiring a State archaeologist to monitor and recover the data since the Indian groups requested that no archaeologist participate. Many archaeologists honored the Indian's request; however, a qualified individual was finally found.

A.5.7 Waste Handling, Emplacement, Related Accidents

1	Technical requirements should prevent the commingling of incompatible wastes.	USEPA (1980c)
2	Technical requirements should prevent the placement of wastes that are incompatible with facility (excavation) liners.	USEPA (1980c)
3	Technical requirements should restrict the disposal of bulk liquid wastes.	USEPA (1980c)
4	Technical requirements should restrict the disposal of containerized liquid wastes.	USEPA (1980c)
5	Technical requirements should restrict the disposal of empty containers.	USEPA (1980c)
6	Automate work as much as possible.	Macbeth et al. (1978)
7	All operating sites specify the segregation of types of waste and the packaging for each.	USDCE (1981b)
8	By observing how workers unload, unbolt, and dump waste containers into trenches, operators have been able to reduce [occupational] radiation doses by up to a factor of two in the past year or so.	USDCE (1981b)
9	The degree of compatibility of treatment and packaging required for disposal with packaging required by DOT regulations will affect whether disposal packaging is done by the generator or at the disposal site.	USDCE (1981b)

- 10 Jacobs et al. (1980)
The handling and disposal of waste radioactive material presents a potential for radiation exposure of operational personnel and a possible source of radionuclide release to the environment. The development and implementation of a safe waste disposal policy requires and understanding of the extent of the potential hazards. Thus, the radiological, chemical, and physical characteristics of the contents of the waste packages must be known and recorded. To assure that future records are maintained adequately requires establishment of techniques for the accurate characterization of the waste upon packaging and techniques for the verification of waste character at the receiving site.
- 11 Jacobs et al. (1980)
Specific items related to space utilization that need additional research development emphasis include:
(1) evaluation of the feasibility of increasing trench depth; (2) evaluation of improved trench orientation; and
(3) evaluation of the need for waste volume reduction.
- 12 Macbeth et al. (1979)
Because the operation personnel [at an SLBF] are trained radiation workers aware of the hazards involved, they will protect themselves and keep to ALARA standards.
- 13 Macbeth et al. (1979)
As compared to present SLB practice, doses due to waste handling accidents might be reduced by, say, 25% by use of air supported weather protection buildings since many of the waste handling operations take place within the dispersion barrier they provide.
- 14 Macbeth et al. (1979)
Accident dose rates might be reduced from those for current SLB practice by a factor of two for SDF disposal, since at least half the waste handling occurs inside the containment provided by the structure.
- 15 Macbeth et al. (1979)
Experience in interim storage of wastes provides some basis for assessment of waste handling accidents.
- 16 USMRC (1981a)
Class A segregated wastes must be placed in disposal units that are sufficiently separated from other units [with wastes not of Class A] that there is no interaction between them.
- 17 USMRC (1981a)
Wastes must be emplaced in an orderly manner that maintains package integrity during emplacement and disposal.
- 18 USMRC (1981a)
Void spaces between waste packages must be filled to reduce future subsidence.
- 19 USMRC (1981a)
Boundaries and location of each disposal unit (e.g., trenches) must be accurately located and mapped by land survey. Three permanent survey marker control points, referenced to USGS or NGS survey control stations must be established on the site.
- 20 Murphy and Holter (1980)
In decommissioning waste relocation activities, the most frequent incident leading to individual exposure is expected to be exhumation of undetected TRU waste.
- 21 Murphy and Holter (1980)
Inhalation doses to decommissioning workers are expected to be negligible for site stabilization and long-term care, since these operations do not normally involve direct contact with buried waste or contaminated soil. However, waste relocation operations may involve the generation of dust containing radioactive particulates, and these operations could result in substantial inhalation doses. The use of respiratory equipment to minimize inhalation doses from those operations which have potential for the generation of airborne radioactivity, is assumed.
- 22 USMRC (1981b)
If, on the other hand, the stable wastes were segregated from the easily degradable wastes, then the potential for degradation of the stable waste would be greatly decreased. Even after several hundred years, the waste mass should still be clearly recognizable as something other than ordinary dirt. It is not credible to suppose that an individual would attempt to construct a house on or grow crops in a location characterized by large stacked metal cylinders filled with concrete. For such cases, exposures would be confined to those received during discovery of the disposed waste. Upon discovery, it is reasonable to expect that the intruder would cease operations while the matter would be investigated. As discussed below under institutional controls (Section 4.3.8), all knowledge about a disposal facility should not be lost and information about the facility would be assessed in determining a proper course of action with respect to the inadvertent intruder. If the individual chose to ignore information about the facility, the event would no longer be considered inadvertent intrusion.
- 23 USMRC (1981b)
Thus, the use of engineered or natural intruder barriers would only be required for the higher activity waste streams. This can be provided in a relatively inexpensive manner through techniques such as layering.

A.6 FACILITY ENGINEERING

- 1 What consideration should be given to a natural waste barrier versus engineered waste barrier comparative analysis? USEPA (1981a)
- 2 For site selection, what is the relative importance of environmental barriers such as geological strata versus engineered controls such as containers? USEPA (1977b)
- 3 What mechanisms are required to prevent site disturbances that may produce environmental impacts? USEPA (1977b)
- 4 Landfill-closure design and post-closure care must consider the type and amount of waste in the facility. USEPA (1981d)
- 5 Landfill-closure design and post-closure care must consider the mobility and expected rate of migration of the disposed waste. USEPA (1981d)
- 6 Landfill-closure design and post-closure care must consider site location, topography and surrounding land use. USEPA (1981d)
- 7 Landfill-closure design and post-closure care must consider climatic conditions in the area. USEPA (1981d)
- 8 Landfill-closure design and post-closure care must consider geological and soil profiles and surface and subsurface hydrology of the site. USEPA (1981d)
- 9 Which techniques are most useful for managing the rate and concentrations of air (gaseous) emissions (from waste-burial sites)? USEPA (1981e)
- 10 Design of engineered barriers to inhibit radionuclide migration (is desirable). Levin (1980)
- 11 Is disposal in man-made structures an acceptable and cost-effective alternative for some FUSRAP waste? Macbeth et al. (1978)
- 12 The major question regarding disposal in man-made structures is its ability to confine the waste under all conditions for the time periods required. Macbeth et al. (1978)
- 13 The site shall, (1) be of sufficient area and depth to accommodate the projected volume of waste and the buffer zone, and (2) include a 3-0 buffer zone of sufficient size to allow unrestricted human use beyond its boundary-including withdrawal of water from aquifers. Falconer et al. (1981)
- 14 The site shall allow waste to be buried either completely above or below the transition between the unsaturated zones. For burial in the saturated zone, preferable earth materials are fine grained with low hydraulic conductivity such that molecular diffusion is the dominant solute migration mechanism. Falconer et al. (1981)
- 15 Waste is generally covered with 1 or 2 meters of soil for SLB and with 10 to 15 meters of soil for IDB. Deichman (1979)
- 16 The impact of engineering activities undertaken to improve waste burial practices[should be evaluated.] Deichman (1979)
- 17 Development of instrumentation to verify waste receipts [is a priority issue.] Deichman (1979)
- 18 Most improvements in SLB [of significance which] have been suggested [as solutions to problems encountered] have been included in NRC proposed regulations (10 CFR 61). USDOE (1981b)
- 19 The [engineering] technical improvements suggested in the literature can readily be implemented in SLB. USDOE (1981b)
- 20 The most serious technical problems in shallow land burial are related to water management. Water provides a primary vehicle both for erosional processes, which can reduce the structural integrity of waste trenches and the trench caps and for migration of the radionuclides. Radionuclide migration in water and subsequent possible exposure to the public, begins with entry of water into the burial trench. The most common ways water comes into contact with the waste are from infiltration of precipitation through the trench caps and/or walls or from erosion leading to exposure of the buried waste. Jacobs et al. (1980)
- 21 Specific items related to water management that need additional research and development emphasis include: (1) field testing and engineering evaluation of techniques for control of infiltration and erosion; and (2) development of a rationale for arriving at a balance between control of infiltration and erosion. Jacobs et al. (1980)
- 22 Engineering improvements to historic SLB should make no significant change in overall non-radiological health impacts, but about a 15% reduction in radiological health impacts. (Macbeth 1979, Tables 3.8 and 3.9) Macbeth et al. (1979)
- 23 Enclosing the radioactive waste in engineered structures may offer advantages over SLB. Some of these advantages have been exploited in certain structures used to store wastes in Canada. Macbeth et al. (1979)
- 24 A structural disposal facility (SDF) would be built of reinforced concrete, for greatest durability and fire resistance at reasonable cost. Both exposed and covered structures could be built, at any appropriate location. Macbeth et al. (1979)
- 25 The specifications shall be developed considering the expected full capacity of tailings or waste systems. USNRC (1980b)
- 26 Sufficient earth cover, but not less than three meters, shall be placed over tailings and wastes to reduce surface exhalation of radon to less than two picocuries per square meter per second. USNRC (1980b)

- 27 Direct gamma exposure from tailings or waste should be reduced to background levels. USNRC (1980b)
- 28 The final disposition of tailings or wastes at milling sites should be such that ongoing maintenances is not necessary to preserve isolation. USNRC (1980b)
- 29 Techniques should be developed and field tested for improving the structural integrity of waste trenches. Candidate techniques include soil compaction, injection of solidifying materials into the void volume of trenches, and addition of expanding clays into waste trenches. Deichman (1980)
- 30 Safety over the long term involves (1) protection of individuals from inadvertent intrusion and contact with the waste in the future, (2) protection of the general public from potential releases to the environment, and (3) stability of the disposed wastes and the site to eliminate need for ongoing maintenance after closure. USNRC (1981a)
- 31 The principal parts of a disposal system which are readily identifiable and will be addressed in the minimum technical requirements are:
 . Characteristics of the disposal site.
 . Method by which the site is designed, the land disposal facility constructed, the waste emplaced, and the site closed.
 . Degree and length of institutional control, surveillance and monitoring of the site after closure. USNRC (1981a)
- 32 For the purpose of this chapter, a geologic repository as defined in Part 60 is not considered a land disposal facility. USNRC (1981a)
- 33 Near-surface disposal facility means land disposal facility in which radioactive waste is disposed of in or within the upper 15-20 meters of the earth's surface. USNRC (1981a)
- 34 Disposal site design [requirements] for other than near-surface disposal [are reserved for future rulemaking]. USNRC (1981a)
- 35 Void spaces between waste packages must be filled to reduce future subsidence. USNRC (1981a)
- 36 Gamma radiation at the surface of covers must be limited to within a few percent of the natural background levels of the site. USNRC (1981a)
- 37 Adequate closure and stabilization measures must be carried out as each disposal unit (e.g., each trench) is filled and covered. USNRC (1981a)
- 38 The waste repository design criteria should reflect NRC's strong historical emphasis on the single failure criterion; accordingly, their development should proceed under the defense-in-depth philosophy. Thus, the process should begin by resolving the proposed waste disposal plan into a few carefully chosen parts, each of which can be regarded as an independent component. The keystone of this proposed licensing process is that each component of the waste management plan must be sufficient to duplicate the isolation performance of the natural state (reference ore body) even if all other parts of the waste management system are arbitrarily assumed to have failed to perform. Cochran et al. (1979)

A.6.1 Water Management

- 1 Technical requirements should prevent water run-on to the disposal facility. USEPA (1980c)
- 2 Technical requirements should control water run-off from the disposal facility. USEPA (1980c)
- 3 Technical requirements should assure that there be no "ponding" of liquids (water) during disposal operations. USEPA (1980c)
- 4 Technical requirements should assure that a facility (excavation) cover is stable and that it is capable of avoiding the buildup of liquids in the landfill by providing a lesser permeability than that of the facility (excavation) liner. USEPA (1980c)
- 5 Landfill-facility leachate and runoff control systems design must consider the physical and chemical characteristics of the disposed waste. USEPA (1981d)
- 6 Landfill-facility leachate and runoff control systems design must consider climatic conditions in the area. USEPA (1981d)
- 7 Landfill-facility leachate and runoff control systems design must consider the volume of leachate or contaminated runoff that could be produced at the facility. USEPA (1981d)
- 8 Landfill-facility leachate and runoff control systems design must consider the available options for managing any leachate or contaminated runoff that is collected at the facility. USEPA (1981d)
- 9 Groundwater monitoring-system design must consider placement and depth of monitoring wells so as to obtain representative samples of the uppermost aquifer, both up and down-gradient from the facility. USEPA (1981d)
- 10 Groundwater monitoring-system design must consider measures such as (well) casings so as to maintain the integrity of monitoring-well bore holes. USEPA (1981d)
- 11 Groundwater monitoring-system design must consider measures which prevent contamination of groundwater samples. USEPA (1981d)
- 12 Which techniques are most useful for managing the generation-rate and quality of leachate produced at a waste-burial facility? USEPA (1981e)
- 13 If [subsurface] fractures are present, fluid loss inhibitions (e.g., grouts) might minimize migration of radionuclides. Deichman (1979)
- 14 Determination of the effects of trench construction on geohydrological parameters [is an important technical issue]. Increased permeability and elevation of the water table at the trench [can occur], and potential changes in hydrological parameters should be monitored. Deichman (1979)

15 USDOE (1981b)
NRC feels that the main effort [connected to leachability] should be put into minimizing water access to the trench in the first place.

16 Jacobs et al. (1980)
Once radionuclides have been leached from the waste trenches and have begun migrating through the ground, the opportunity for control has been greatly diminished. Buffer zones between the actual burial trenches and the site perimeter would increase the opportunity for detection and control of radionuclide migration.

17 Jacobs et al. (1980)
Both infiltration and erosion can be controlled by water management practices. Erosion control practices include a good vegetative cover, a permeable cap, and shallow slope; whereas measures for infiltration control include limiting vegetation, an impervious cap, and a high slope to promote rapid drainage. Hence, management practices that reduce erosion may enhance infiltration, and vice-versa. Selection of a suitable burial site management program must consider a balance between the control of infiltration and erosion.

18 Jacobs et al. (1980)
The control of infiltration of water into trenches is a major step in the prevention or minimization of contact between water and buried waste. Studies have identified many of the factors that control water infiltration, and have led to suggestions for practices for reducing it. Most of the factors and mitigating practices relate to cap and trench design. Pumping accomplishes the greatest reduction in trench water, but it is by far the least cost-effective and should be considered a favorable management option only on a short-term basis.

19 Jacobs et al. (1980)
A comprehensive evaluation of water management to control infiltration is needed. A literature review should be made of field experience at both radioactive and nonradioactive burial facilities. Much of the experience at operational facilities may not be reported in the literature; thus, interviews or questionnaires may be necessary to retrieve the desired information. The findings should be used to identify techniques that have technical promise or which have been useful at specific sites. These techniques should then be subjected to experimental examination in field situations with particular attention given to imposing both controlled conditions to enable intercomparison of techniques and ranges of anticipated conditions at sites of potential application. The anticipated conditions should include not only the native hydrogeological characteristics of the site, but also the changes in parameters that may occur from operation of the facility or from nearby construction.

20 Macbeth et al. (1979)
Impermeable covers for burial trenches could be made from many materials: common clay, asphalt, plastic membranes, concrete, stainless steel. Most require soil covering for protection against erosion, root or animal intrusion, or sunlight.

21 USNRC (1980b)
While the primary method of protecting groundwater shall be isolation of tailings, disposal involving contact with groundwater will be considered provided it is demonstrated that the groundwater will not be degraded from current or potential uses.

22 USNRC (1981a)
Any groundwater discharge to the surface within the disposal site must not originate within the hydrogeologic unit used for disposal.

23 USNRC (1981a)
Covers must be designed to prevent water infiltration, to direct percolating or surface water away from the waste and to resist degradation by surface geologic processes and biotic activity.

24 USNRC (1981a)
Site must be designed to eliminate contact of water with waste during storage, contact of standing water with waste during disposal, and contact of percolating or standing water after disposal.

A.6.2 Erosion and Intrusion Control

1 USEPA (1981d)
Landfill-closure design and post-closure care must consider characteristics of the cover including material, final surface contours, thickness, porosity, and permeability, slope, length of run of slope, and type of vegetation on the cover.

2 Macbeth et al. (1978)
Deeper land burial LB, with final cover of 10 to 20 m of clean soil, would largely avoid certain shallow land burial problems: inadvertent encounter with waste, water infiltration, erosion to expose waste before it decays to innocuous residual activity.

3 Deichman (1979)
Development and evaluating erosion and intrusion control barriers [is a priority technical issue]. [It must be] consistent with abiotic, edaphic, and biotic conditions, and stable over long periods of time.

4 Jacobs et al. (1980)
Both infiltration and erosion can be controlled by water management practices. Erosion control practices include a good vegetative cover, a permeable cap, and shallow slope; whereas measures for infiltration control include limiting vegetation, an impervious cap, and a high slope to promote rapid drainage. Hence, management practices that reduce erosion may enhance infiltration, and vice-versa. Selection of a suitable burial site management program must consider a balance between the control of infiltration and erosion.

5 Jacobs et al. (1980)
Control of trench cap erosion is needed to minimize the contact between water and the buried waste. Erosion may damage the structural integrity of the trench cap (1) promoting infiltration and (2) exposing waste for subsequent transport by water and air. The technical issue is to identify and quantify those factors which influence the erosion of trench caps.

6 Jacobs et al. (1980)
Management practices for erosion control that should be evaluated for their effectiveness include the use of (1) various types of vegetative cover, (2) contouring, (3) diversion channels for control of surface water flow (4) various types of physical materials for trench caps, and (5) trench cap maintenance.

7 Jacobs et al. (1980)

In evaluating erosion control measures, consideration should be given to their ability to remain stable over long periods of time and to provide protection against intrusion by deep-rooted plants and by small burrowing animals as well as their effectiveness in providing short-term erosion control.

8 Jacobs et al. (1980)

The adoption of optimum practices of control of infiltration at a burial site may be at cross practices with optimum erosion control. Good water management practice must consider the effects of possible practices on both infiltration and erosion and arrive at the policy best suited for optimum water management at the site. This balance will likely vary from site to site, reflecting differences in hydrology, climate, topography, soil mechanics, geology, etc.

9 USHRC (1980b)

Embankment and cover slopes shall be relatively flat after final stabilization. In general, slopes should not be greater than about 5 horizontal to 1 vertical.

10 USHRC (1980b)

A full self-sustaining vegetative cover shall be established or a rock cover employed to reduce wind and water erosion to negligible levels. Rock covering of slopes may not be necessary when top covers are very thick or inherently erosion-resistant, slopes are very gentle, and there is negligible upstream rain catchment and good wind protection.

11 Deichman (1980)

The breakdown of waste-trench covers or seals may lead to a variety of problems, such as removal of radioactive materials from the burial site by wind or water erosion, by subsurface transport resulting from increased infiltration of precipitation, and by incorporation into flora and fauna in contact with waste trenches or with waste migrated from trenches.

12 Deichman (1980)

At several disposal sites, trench caps have failed due to the formation of voids as the waste and waste packages deteriorate and then compact. Failure of the trench cap allows excessive infiltration of precipitation and destroys the effectiveness of any biobarrier that may have been installed, resulting in increased rates of radionuclide migration and a safety hazard to operations staff. These failures could be prevented or ameliorated by compacting the waste in situ to reduce void volumes; improving the cap strength, providing better structural support for the cap, or using standardized modular containers containing compacted waste which permit compact stacking.

13 USHRC (1980a)

Deciding what should be a minimum cover thickness is a matter of judgement. The staff considers, however, a minimum cover thickness of 3m (10 ft) to be a reasonable lower limit.

14 USHRC (1980a)

Site design features for erosion control that should be considered include: upstream rainfall catchment areas and flood erosion potential; topographic features for wind protection; embankment and cover slopes, with emphasis on avoiding slopes greater than 1:10 (vertical:horizontal); and adequate self-sustaining vegetative cover or rock cover.

15 USHRC (1981a)

Covers must be designed to prevent water infiltration, to direct percolating or surface water away from the waste and to resist degradation by surface geologic processes and biotic activity.

16 Murphy and Holter (1980)

Plant roots, in addition to uptake of radionuclides, are also instrumental in the mechanical breakdown of buried waste and overburden material. Most reports of biological interaction with waste have involved plants.

17 Murphy and Holter (1980)

A rock layer provides a barrier to digging and burrowing animals, in principal, but its effectiveness for all species of significance is not firmly established (e.g., prairie dogs).

18 USHRC (1981b)

As discussed earlier in Section 2.2.4 regarding biological barriers, installation of an engineered intruder barrier such as the one described above would tend to become an extremely expensive enterprise unless subsidence of the disposal trench cap had been eliminated. The whole point of an engineered intruder barrier is that once it is installed, it is difficult to remove. Any repairs or trench restabilization work required after barrier installation would be both expensive and difficult.

19 USHRC (1981b)

The waste form should be effective against intrusion for several hundred years. After several hundred years (i.e., on the order of 500 years), most of the shorter-lived radionuclides will have decayed away, leaving the longer-lived radionuclides. The reduction in hazard after 500 years takes place at a much slower rate. Attempting to reduce intruder impacts through waste form beyond 500 years would really not accomplish much in the way of additional protection.

20 USHRC (1981b)

Thus, the use of engineered or natural intruder barriers would only be required for the higher activity waste streams. This can be provided in a relatively inexpensive manner through techniques such as layering.

A.6.3 Burial Trenches

1 USEPA (1981d)

Landfill-facility (trench) liner design must consider the physical and chemical characteristics of the waste.

2 USEPA (1981d)

Landfill-facility (trench) liner must consider the pressure head of leachate on the liner

3 USEPA (1981d)

Landfill-facility (trench) liner design must consider the climatic conditions in the area.

4 USEPA (1981d)

Landfill-facility (trench) liner design must consider the permeability of the liner material including compaction density and moisture content where earthen materials are present.

5 USEPA (1981d)

Landfill-facility (trench) liner design must consider the physical and chemical properties of the soil underlying the facility that supports any emplaced liner.

6 USEPA (1981d)

Landfill-facility (trench) liner design must consider the potential for damage to the liner system that could occur during installation of any emplaced liner.

- 7 Solid waste is usually buried in the shallow surface soil to subsurface geology transition zone. [Since] this zone has not received much geologic study, [there are] uncertainties as to subsurface hydrology. Macbeth et al. (1978)
 - 8 Burial trenches are or could be designed to contain critical nuclides for several hundred years. Macbeth et al. (1978)
 - 9 Determination of methods to prevent or minimize structural failures of trenches [is a priority technical issue]. Candidate techniques include soil compaction, injection of solidifying material into the void volume of trenches, addition of expanding clays into waste trenches. Deichman (1979)
 - 10 Determination of the effects of trench construction on geohydrological parameters [is an important technical issue]. Increased permeability and elevation of the water table at the trench [can occur], and potential changes in hydrological parameters should be monitored. Deichman (1979)
 - 11 The backfill material covering trenches has sagged and collapsed in some trenches at ORNL Haney Flats. Sagging of trench covers can enhance the infiltration of water into the trenches. Jacobs et al. (1980)
 - 12 Modifications in trench orientation and geometry at shallow land burial sites may be appropriate. Trenches at a number of arid sites could be deepened to increase available storage volume. Increasing the width of trenches and placing them closer together could also improve space utilization, but care must be taken not to destroy the integrity of the trench walls. Provisions must be allowed for a buffer zone between the trenches and the site boundary. Jacobs et al. (1980)
 - 13 Specific items related to space utilization that need additional research development emphasis include: (1) evaluation of the feasibility of increasing trench depth; (2) evaluation of improved trench orientation; and (3) evaluation of the need for waste volume reduction. Jacobs et al. (1980)
 - 14 In Europe, burial in coarse sand has been successful by placing a layer of fine sand over the coarse trench bottom. Water penetrating the waste and fine sand is held up at the coarse-fine interface because of the stronger capillary attraction in the fine sand. This is effective only where the ground is not saturated. Macbeth et al. (1979)
 - 15 Improvements in burial trench design could include:
 - . Inclined trench bottom plus sump, to avoid "bathtub effect".
 - . Compacted clayey or silty soil under trench bottom, for enhanced ion exchange.
 - . Coarse sand layer between waste and trench bottom, to ensure that water drains away from the waste.
 - . Drainage ditches, filled with crushed rock along bottom of each trench wall.
 - . Sump or drain at lower end of trench, with means of sampling and pumping accumulated water.
 - . Process all water entering sump or drain, e.g. via an ion exchange column.
 - 16 Trenches could be lined with concrete, as is presently done for waste storage in Canada. Macbeth et al. (1979)
 - 17 Steps shall be taken to reduce seepage of toxic materials into groundwater, including consideration of installation of low permeability bottom liners. When clay liners or thin in situ clay soils are to be relied upon, tests shall be run long enough to reveal any effects which may occur (deterioration has been observed to occur rather rapidly after about 9 months of exposure, in some cases). USNRC (1980b)
 - 18 Site design for preventing seepage of toxic materials that should be considered include installation of impermeable bottom liners and neutralization to prevent immobilization of toxic substances. USNRC (1980a)
 - 19 A buffer zone must be maintained and shall extend at least 100 feet outward from the outermost waste disposal units. USNRC (1981a)
- #### A.6.4 Waste Emplacement
- 1 Automate work as much as possible. Macbeth et al. (1978)
 - 2 Low density waste can compact to produce voids in trenches, resulting in increased water infiltration, trench cap subsidence, and in some cases exposing the waste. Lipton (1981)
 - 3 A fire or explosion in a burial trench would be of major concern. Lipton (1981)
 - 4 Use of standard packages containing compacted waste would permit efficient, modular stacking configurations which would alleviate many operational problems. Deichman (1979)
 - 5 Compactors currently in use reduce waste volume by a factor of 2, although newer machines are up to a factor of 4. USDOE (1981b)
 - 6 In areas having heavy rainfall, the use of a movable structure for a weather shield during trench filling operations may be useful. Macbeth et al. (1979)
 - 7 Improved overall weather shielding, e.g. a weather shield building during trench filling and moisture barriers over the pits, could decrease the importance of adverse climatic conditions in site selection. Macbeth et al. (1979)
 - 8 Engineering improvements, e.g. in weather shielding, may offer risk/cost/benefit tradeoffs against transportation costs and risks. Macbeth et al. (1979)
 - 9 As compared to present SLB practice, doses due to waste handling accidents might be reduced by, say, 25% by use of air supported weather protection buildings since many of the waste handling operations take place within the dispersion barrier they provide. Macbeth et al. (1979)

- 10 Macbeth et al. (1979)
Experience in interim storage of wastes provides some basis for assessment of waste handling accidents.
- 11 USNRC (1981a)
Class A segregated wastes must be placed in disposal units that are sufficiently separated from other units (with wastes not of Class A) that there is no interaction between them.
- 12 USNRC (1981a)
Stability requirements are intended to assure for at least 150 years that the waste does not degrade and promote disposal unit failure leading to water infiltration.
- 13 USNRC (1981a)
Waste must have structural stability, provided by the waste form, by processing to a stable form, or by disposal container or structure. A stable form will maintain its dimensions within 5% and its form under expected compressive loads of 50 psi and other factors (e.g., moisture, microbial activity, radiation, and chemical effects, etc.)
- 14 Murphy and Holter (1980)
Stabilization procedures would normally be included as part of burial ground operations. For sites where adequate site/waste stabilization has not been performed during the operating phase, these activities would be performed at the conclusion of burial operations prior to termination of the operating license.
- 15 Murphy and Holter (1980)
In some instances assumptions are made that may not be conservative. Examples of possible nonconservation are the assumption that corrosion of slit trench canisters and of the stainless steel components inside the canisters is minimal during the 200-year period of administrative control site, and the neglect of the effect of chelating agents in increasing the mobility of certain radionuclides. Such assumptions are made because of the inadequacy of the data base that would lead to meaningful quantitative results.
- 16 Murphy and Holter (1980)
Enclosure candidates with demonstrated feasibility, for use as weather protection and for containment during exhumation, include: wind break, pole shed, air supported envelope, plastic greenhouse, metal building.
- 17 USNRC (1981b)
Use of weather shielding can result in additional waste handling problems. Even the largest weather shields have limited headroom. A tension structure with a clearspan of about 36 m can provide about 12 m of headroom at the center of the arch. This provides a serious limitation on emplacement of wastes from cranes located at relatively shielded positions at the ground surface. Most waste emplacement would therefore have to be performed by transporting the wastes directly into the trenches, and locating them by means of forklifts or small "cherry picker" cranes which operate directly in the trench floor. The use of weather shielding necessarily implies that the waste emplacement work force spends more time in relative proximity to the waste, and therefore higher occupational doses are anticipated. It is estimated that occupational doses will increase by about 15% with the use of weather shielding.

A.6.5 General Site Requirements and Desiderata

- 1 USEPA (1978)
Reliance on institutional control of disposed waste should be minimized. Primary reliance should be placed on engineered and natural barriers to protect the environment and public health.
- 2 USDDE (1981a)
Technical and economic factors affecting licensing and site design include requirements for: design, pre-operational monitoring, waste acceptance, operations and environmental modeling, closure, operational and extended care funding.
- 3 USDDE (1981b)
Technical problems at the three closed [disposal] sites fall into four categories:
1. Site-specific; mainly water control.
2. Waste-specific; identification, form, migration modes.
3. Operation-specific; trench-structure management, security.
4. Performance-specific; including monitoring, performance standards.
- 4 USDDE (1981b)
The basic technical evaluation questions are:
1. Given a limit on doses that can be [allowed to be] delivered in occupational exposure or to the general public, to what extent can a disposal alternative satisfy this requirement with current technology?
2. If current technology is inappropriate, how feasible are the needed improvements?
3. How widely available are sites with the hydrogeologic characteristics needed for a given disposal technique?
- 5 Jacobs et al. (1980)
Technical issues related to problems experienced at existing shallow land burial facilities, which need to be resolved by further research and development in order to develop improved management practices and provide information for remedial actions at both closed and currently operating sites, may be grouped into seven major areas: (1) water management; (2) radionuclide migration; (3) waste inventory records; (4) performance monitoring and evaluation; (5) prediction capabilities; (6) space utilization; and (7) management practices.
- 6 Macbeth et al. (1979)
More accurate modeling of effects of unsaturated flow conditions, percolation, evapotranspiration, and geometric distributions of waste within the disposal site [may be needed].
- 7 IAEA (1981)
In general, primary reliance should be placed on the natural protection offered by the selected site. An ideal site is not always available, and appropriate measures such as additional barriers (conditioning of waste, engineered structures, etc.) can be used to provide additional assurance that any detriment to the environment is within acceptable limits. The design should take into account site characteristics, use engineered

methods to improve radionuclide retention characteristics (reducing water infiltration is the most important near-term consideration), and provide appropriate facilities for site functions (waste receipt, repository construction, interim storage facilities, laboratory facilities, personnel facilities, etc.).

- 8 USNRC (1981a)
Migration analysis [in license applications] must identify and differentiate between roles of natural site characteristics and design features in isolating and segregating the wastes.
- 9 USNRC (1981a)
Site design must be directed toward long-term isolation and avoidance of active maintenance.
- 10 USNRC (1981a)
Site design and operation must be compatible with [an adequate] site closure and stabilization plan.
- 11 USNRC (1981a)
Site design must complement and improve the site's natural characteristics in re performance objectives.
- 12 USNRC (1981a)
Surface features must direct water drainage away from disposal units at velocities and gradients which will not result in erosion requiring future active maintenance.
- 13 Murphy and Holter (1980)
Site/waste stabilization plans are summarized by Murphy & Holter in Table 2.8-1 for and grid western site and a humid eastern site. Principal actions are listed for minimal, modest, and complex plans.
- 14 Murphy and Holter (1980)
Long-term care includes administrative control, environmental surveillance, and site maintenance.
Administrative control includes:
 - . control site access
 - . coordination of surveillance and maintenance activities.
 - . control of land-use and property-development activities.
 - . performance of necessary records maintenance
Environmental surveillance includes:
 - . collection of environmental samples
 - . analysis of environmental samples
 - . records maintenance
Site maintenance includes:
 - . maintenance and repair of fences, gates, monitoring systems, etc.
 - . erosion control
 - . trench cap repair
 - . water infiltration control
 - . vegetation management.
- 15 Murphy and Holter (1980)
Decommissioning modes for SLB sites correspond to those for fuel cycle facilities as follows: waste relocation/dis-entailment, stabilization/entombment, and long-term care/safe storage. Definitions of actions, facility status, and land use category for these modes are given by Murphy and Holter in Table 4.1-1.

- 16 Murphy and Holter (1980)
Potential site/waste stabilization activities include:
 - . engineered routing/flow control of ground and surface water
 - . modification of trench caps to minimize water infiltration into the trenches
 - . stabilization of the land surface and erosion control
 - . grouting or injection of chemicals into the waste matrix to reduce the mobility of radionuclides
 - . control of plants and animals that might disturb surface stabilization measures or transport radioactivity from the trenches
 - . erection of physical barriers to control human activities at the site.
- 17 Murphy and Holter (1980)
Murphy and Holter, in Table 10.1-1, indicate the applicability of 19 identified site/waste stabilization techniques to the control of 12 types of release mechanisms.
- 18 Murphy and Holter (1980)
Effectiveness of nineteen prospective stabilization techniques for control of twelve radionuclide transport mechanisms is rated by Murphy and Holter in Table 10.2-1.
- 19 Valore and Lararsh (1978)
There should clearly be an exclusion zone around the facility, but a low population area is probably not necessary.
- 20 USNRC (1981b)
The NRC had in mind at the time of the Advance Notice that the use of multiple barriers (natural and man-made, such as waste packaging form, and content) to radioactive waste movement and human contact with waste should be emphasized.

A.6.6 Historical Examples

- 1 Lipton (1981)
Transport of vapor phase tritium through joints and porous zones has been observed.
- 2 Jacobs et al. (1980)
Water has come into contact with waste in burial trenches at six of the eleven major land burial facilities. Solutions for some of these water problems have been implemented or proposed.
- 3 Murphy and Holter (1980)
In November 1973, Kentucky instituted a special six-month environmental monitoring study to identify the source and scope of increased levels of environmental radioactivity in the Maxey Flats site environs. The study report concluded that the burial ground was contributing radioactivity to the local environment; that the activity detected did not create a public health hazard.
- 4 Murphy and Holter (1980)
In 1972, a test excavation was made in a burial trench at the Savannah River Laboratory that had been filled in 1958. The waste articles were in exceptionally well-preserved condition. Radioactivity levels encountered at the excavation were essentially at normal area background.

5 Murphy and Holter (1980)
A second waste retrieval program at INEL, the Early Waste Retrieval project was initiated in FY 1976 to investigate the problems associated with retrieval and repackaging of damaged and boxed TRU waste material that was buried between 1960 and 1963. The waste material and drums were found to be randomly distributed in the trenches. Virtually all the waste drums were severely rusted and otherwise badly deteriorated. Several of the drums contained liquids. In some cases, the liquids leaked from the drums during excavation. In all cases, the spread of contamination was confined within the OAC building.

6 Shapiro (1981)
For example, government trenches at the Hanford Reservation which contain sixteen million cubic feet of low-level solids are frequently burrowed into by desert animals, and when I visited there in 1979 I was shown (from a distance) a sage-brushed covered tract of about four square miles which had to be patrolled by health physicists, who vacuumed up radioactive droppings and the radioactive carcasses of rabbits, coyotes, and other creatures.

7 Shapiro (1981)
"So far during the lifetime of this site, we have never had waste sitting in water, and I think that is saying a lot." It may be saying too much. A 1978 Brookhaven National Laboratory survey found significant levels of radioactive cesium, cobalt, and manganese in water drawn from Barnwell trenches.

A.6.7 Deeper Burial

1 Macbeth et al. (1978)
Solid waste is usually buried in the shallow surface soil to subsurface geology transition zone. [Since] this zone has not received much geologic study, [there are] uncertainties as to subsurface hydrology.

2 Macbeth et al. (1978)
Deeper land burial would [open] the possibility of reclaiming old strip mines or other poor terrain.

3 Macbeth et al. (1978)
Deeper land burial LB, with final cover of 10 to 20 m of clean soil, would largely avoid certain shallow land burial problems: inadvertent encounter with waste, water infiltration, erosion to expose waste before it decays to innocuous residual activity.

4 Adam and Rogers (1978)
The critical nuclide and pathway for low-specific-activity solids such as mill tailings and coal ash is the radon recolonization scenario (inhalation of radon by a reclamer, e.g., by someone living in a house built on the site). The impact from this exposure event can be reduced by two orders of magnitude by burying the coal ash or tailings sufficiently deep to preclude exposures to unsuspecting reclaimers (about 10 m).

5 Macbeth et al. (1979)
Many former strip mines are available [for IDB sites], where the recontouring [for erosion control] could be environmentally advantageous.

6 Macbeth et al. (1979)
IDB will generate non-radiological impacts about the same as for SLB.

7 Macbeth et al. (1979)
Radiological impacts for IDB, as estimated, would be less than for SLB by a factor of 5 to 6. Percolation of surface water down to the waste is retarded, and inhalation and food pathway exposure virtually eliminated.

8 Macbeth et al. (1979)
Although the technique of IDB for disposal of LLH has not been demonstrated, no technological problems in implementing it are foreseen.

9 Macbeth et al. (1979)
IDB has also been suggested for disposal of radioactive uranium mill tailings. (FDOU-211, May 1978)

10 USNRC (1980b)
The "prize option" for tailings disposal is placement below grade either in mines or specially excavated sites (that is, where there is no need for any specially constructed retention structure).

11 USNRC (1981a)
Any waste which, after the 100 year period of institutional control, would cause exposure greater than 500 mrem to an inadvertent intruder is identified as class C intruder waste and must be protected by deeper burial (a minimum of 5 meters below grade) or an equivalent natural or engineering barrier.

12 USNRC (1981a)
Class C waste must be buried deeper than other waste, or, if site conditions prevent this, protected by engineering barriers. The assumed effective life of these barriers is 500 years, and the maximum radionuclide concentration for all wastes must, in general, be such that at the end of the 500 year period no danger to public health and safety remains.

13 USDOE (1981d)
The Tioga Mine Drainage Abatement Project (Hard Township, PA.) and Absaloka Coal Mine (Big Horn County Montana) provide important experience in control or mitigation of water pollution problems, and have significantly influenced current mining regulations. It may be noted that more than 592,000 cubic yards of fill were used in reclaiming strip mine pits in Tioga.

14 USNRC (1981b)
Both the design and operation of the example intermediate depth disposal facility differ significantly from the reference disposal facility described in Appendix E. The excavation is assumed to be a circular open-pit with a spiral access road leading down into the excavation. The excavation is roughly circular with a 410 m diameter at the base of the excavation and a 480 m diameter at ground surface. The maximum depth of the excavation is 34 m. The disposal cell consists of three layers of waste each 5 m thick. Each layer of waste is replaced by forklifts and boom cranes within the excavation. Random emplacement is assumed throughout the operations with a void space utilization of 50% assumed. For purposes of analyses, an average annual waste input of 50,000 m³ (1.77 million ft³) over 20 years duration is assumed.

15 USNRC (1981b)
Commentors who offered an opinion on Intermediate Land Burial as an LLH method were divided. The comment offered most frequently was that the bulk of the waste would be contained longer, but the increased cost would not be justified by the relatively insignificant hazard.

A.6.8 Retrievability

- 1 Retrievalability is not an issue that requires consideration for the burial of low-level naturally radioactive wastes. USEPA (1977b)
- 2 Site design considerations should not rely on retrievalability. Macbeth et al. (1978)
- 3 Waste relocation involves the exhumation of buried waste, repackaging of the waste if necessary, and reburial of the waste at another disposal site or in another trench on the same site. Exhumation of waste originally buried without any intent of later retrieval is an expensive and time-consuming operation that has a potential for significant radiation exposure to decommissioning workers. Therefore, waste relocation would likely be considered only in situations where other decommissioning procedures are inadequate to ensure that future risk from the facility is within acceptable bounds. Murphy and Holter (1980)
- 4 A second waste retrieval program at INEL, the Early Waste Retrieval project was initiated in FY 1976 to investigate the problems associated with retrieval and repackaging of drummed and boxed TRU waste material that was buried between 1960 and 1963. The waste material and drums were found to be randomly distributed in the trenches. Virtually all the waste drums were severely rusted and otherwise badly deteriorated. Several of the drums contained liquids. In some cases, the liquids leaked from the drums during excavation. In all cases, the spread of contamination was confined within the OAC building. Murphy and Holter (1980)
- 5 Engineered storage could be provided for wastes likely to require relocation at some future time. Doherty (1978)
- 6 He feels that it will be very important to have low level waste be removable in the event of events that make dispersal a possibility.

A.7 RISK AND UNCERTAINTY

1	How should waste disposal rulemaking consider the aspect of risk?	USEPA (1981a)
2	Should the procedure for rulemaking consider both "normal" and "accident" impact factors?	USEPA (1981a)
3	For the burial of low-level wastes, are environmental accidents of major concern? What kind? For how long a time period?	USEPA (1977b)
4	Risks due to radioactive wastes (disposal) should be unacceptable unless more complete isolation is unreasonable in view (terms) of technical, economic, and social considerations.	USEPA (1978)
5	No prescription can be stated at this time (April 1978) for judging an adequate degree of protection for radioactive waste independent of circumstances.	USEPA (1978)
6	The waste-disposal risk assessment must be performed as responsibly as possible.	USEPA (1978)
7	The waste-disposal risk assessment should include a survey of public opinion and, further, dissemination of the assessment results to the public.	USEPA (1978)
8	Who should perform waste-disposal risk assessments (EPA, NRC, National Academy of sciences,)?	USEPA (1978)
9	A waste-disposal risk assessment should identify those physical parameters which most influence risk and those parameters which have little effect on calculated risk.	USEPA (1978)
10	A waste-disposal risk assessment should identify processes and events which significantly contribute to either release of wastes or the human health consequences of release.	USEPA (1978)
11	A waste-disposal risk assessment should be as realistic as possible.	USEPA (1978)
12	A waste-disposal risk assessment should consider resultant (from releases) health effects and assumptions of the relation of radiation dose to health effects.	USEPA (1978)
13	A waste-disposal risk assessment should consider movement of radioactivity through the environment and the resultant human uptake, taking into account the effect of assumptions of future climate, land use, and demography.	USEPA (1978)
14	A waste disposal risk assessment should address mechanisms of local release of wastes from the disposal site and the likelihood of such release.	USEPA (1978)
15	A waste disposal risk assessment should consider physical and chemical characteristics as well as persistence of waste.	USEPA (1978)
16	Risk assessment should be done for the life of the radiation.	USEPA (1978)
17	To determine the population at risk, the individuals probabilities should be multiplied by the total population.	USEPA (1978)
18	Statistical risk to the total population should be included in rulemaking considerations.	USEPA (1978)
19	What risk is acceptable for radioactive waste disposal?	USEPA (1978)
20	Public health, safety, and full-cost analysis are all essential components in the consideration of waste-disposal controls.	USEPA (1978)
21	What will be the effects of accidents other than those arising from release of radioactive material?	USDOE (1981c)
22	Cleanup standards should be risk-related. They should limit the harm done to people.	USEPA (1980a)
23	Disposal site owner/operator should provide a prediction of the human health risks (chronic and acute) presented by the constituent (of disposed waste) at the concentration found in the water used by humans in the vicinity of the facility.	USEPA (1980c)
24	The comment "Studies to date conclude that (disposal waste) migration does not pose any present threat to public health and safety" downplays the risk that such a threat could develop in the future.	USDOE (1979)
25	What assumptions can one make about future groundwater and surface-water use and of land-use patterns in order to predict future exposures (to disposed waste)?	USEPA (1981e)

- 26 What factors are most likely to undercut the accuracy of a prediction about environmental exposures (to disposed waste)? USEPA (1981e)
- 27 Risk, benefit, and cost analysis of each remedial action and disposal option will be considered in selection of the proposed remedial action, and [will cover] environmental, technical and public opinion issues. USDOE (1980b)
- 28 The site shall be located in areas where climatological conditions allow reliable performance predictions. Recurrence probabilities of any extreme meteorological events which could threaten site performance shall be predictable with reasonable confidence. Falconer et al. (1981)
- 29 The safety assessment portion [of the environmental and safety report] examines consequences of potential operational accidents, natural disasters, radionuclide migration, and severe climatic conditions. USDOE (1981a)
- 30 Determination of the potential hazards from long-lived radionuclides [is a priority technical issue]. Deichman (1979)
- 31 Effect of off-normal weather conditions on burial sites [is an important technical issue]. "Catastrophic" storms likely at burial sites in intervals of decades or centuries [as well as more frequent severe weather conditions] are to be taken into account. Deichman (1979)
- 32 Assessment of the effects of severe weather and/or "catastrophic" storms depends on on-site study in conjunction with the best available information on conditions which may be expected to occur and on the frequency of their occurrence. Literature search for surrogate data, empirical equations for water and wind erosion and experimental tests of such can provide initial assessment. Deichman (1979)
- 33 [There is] an interminable list of "what if" questions: What if the weather pattern changed leading to greatly increased or decreased rainfall? What if drainage patterns were changed by earthquakes? What if a new ice age moved about large quantities of soil? What if the site were forgotten and used to grow who knows what crops? Cohen and Jow (1978)
- 34 Most states impose restrictions such as monthly volume limits, predisposal inspection, prohibitions against certain types of waste based on waste form (e.g. organic liquids), waste source (e.g. medical vs. non-medical), or location of the generator (in state vs. out of state). USDOE (1981b)
- 35 Classification by radiological hazard would be based on hazards all along the path of LLW management: handling, packaging, transportation, and ultimate disposal. USDOE (1981b)
- 36 Classification by total hazard is deemed desirable by the states, which [should] enhance development of regional compacts and disposal sites, and it should achieve greater protection of the public than any alternative classification scheme. However, costs of waste management and disposal would increase substantially, and regulation development and enforcement would significantly impact on regulatory agencies. USDOE (1981b)
- 37 Chemical hazards of wastes in SLB can be due to constituents whose degradation can be enhanced by appropriate burial conditions, whose lifetime is essentially infinite, or which synergistically increase radiological hazards. EPA regulations require a 30 year post-closure control period for hazardous wastes. USDOE (1981b)
- 38 Beyond analysis of generic disposal alternatives, site-specific studies are needed. These should include sensitivity analyses, improved impact estimation methods and models, methods for combining long-term and short-term impacts including probabilistic considerations. Macbeth et al. (1979)
- 39 Construction crew sizes, hence the worker population subject to occupational hazards, has been estimated by dividing estimated capital costs by a single factor for labor. Macbeth et al. (1979)
- 40 Exposures associated with transportation of LLW are based on 1.8 x 10⁻⁵ man-rev/car mile developed in WASH-1235. Macbeth et al. (1979)
- 41 To date there has been little information [provided] which would allow the public to make rational assessments of the risks associated with radioactive wastes [and to compare them] to other activities ensuing from modern technology. Macbeth et al. (1979)
- 42 Events such as the Three Mile Island incident tend to instill suspicion of all risk calculations, since to the public the fact that [it did] occur appears to make previous statements that it would be unlikely seem purposely misleading. Macbeth et al. (1979)
- 43 As compared to present SLB practice, doses due to waste handling accidents might be reduced by, say, 25% by use of air supported weather protection buildings since many of the waste handling operations take place within the dispersion barrier they provide. Macbeth et al. (1979)
- 44 Accident dose rates might be reduced from those for current SLB practice by a factor of two for SDF disposal, since at least half the waste handling occurs inside the containment provided by the structure. Macbeth et al. (1979)
- 45 The level of safety which can and should be achieved must be considered. The level of safety can be designed for prevention (e.g., stepping rainwater infiltration into the waste cell) or for mitigation (e.g., minimizing the amount of leachate leaving the waste cell) or for both. An important consideration in evaluating the effectiveness of a safety design feature is the predictability of its long-term performance. Experience at shallow land burial sites have shown that many of the safety features were not designed with long-term performance predictability as a primary consideration, and as a consequence they have neither prevented nor mitigated some of the difficulties. Oztunali (1980)
- 46 As stated, the staff considers that conservative design of tailings disposal programs and careful siting of disposal impoundments can provide reasonable assurance that the tailings will remain isolated for very long periods of time. However, the very long-term performance of tailings isolation USNRC (1980a)

(that is, several thousands of years into the future and beyond) will be governed by climatic and geologic forces which cannot be predicted precisely. Therefore, there is uncertainty about very long-term effects. However, radioactivity in the tailings, unlike high level nuclear waste, poses a chronic as opposed to an acute hazard. Long and sustained exposure to radioactivity in the tailings pile would be required to produce detectable adverse effects. If degradation or failure of isolation were to occur, it would not lead to catastrophic radiation effects. There would be ample time to take corrective action.

47 USHRC (1981a)

Analysis [in license applications] of protection of individuals during operation must assess expected exposures due to routine operations and likely accidents during handling, storage, and disposal of waste.

48 Murphy and Holter (1980)

Waste relocation involves the exhumation of buried waste, repackaging of the waste if necessary, and reburial of the waste at another disposal site or in another trench on the same site. Exhumation of waste originally buried without any intent of later retrieval is an expensive and time-consuming operation that has a potential for significant radiation exposure to decommissioning workers. Therefore, waste relocation would likely be considered only in situations where other decommissioning procedures are inadequate to ensure that future risk from the facility is within acceptable bounds.

49 Murphy and Holter (1980)

In November 1973, Kentucky instituted a special six-month environmental monitoring study to identify the source and scope of increased levels of environmental radioactivity in the Maxey Flats site environs. The study report concluded that the burial ground was contributing radioactivity to the local environment; that the activity detected did not create a public health hazard.

50 Murphy and Holter (1980)

In 1972, a test excavation was made in a burial trench at the Savannah River Laboratory that had been filled in 1958. The waste articles were in exceptionally well-preserved condition. Radioactivity levels encountered at the excavation were essentially at normal area background.

51 Murphy and Holter (1980)

A second waste retrieval program at INEL, the Early Waste Retrieval project was initiated in FY 1976 to investigate the problems associated with retrieval and repackaging of drummed and boxed TRU waste material that was buried between 1960 and 1963. The waste material and drums were found to be randomly distributed in the trenches. Virtually all the waste drums were severely rusted and otherwise badly deteriorated. Several of the drums contained liquids. In some cases, the liquids leaked from the drums during excavation. In all cases, the spread of contamination was confined within the OAC building.

52 Murphy and Holter (1980)

In decommissioning waste relocation activities, the most frequent incident leading to individual exposure is expected to be exhumation of undetected TRU waste.

53 Murphy and Holter (1980)

Safety analyses for decommissioning include radiological and nonradiological hazards to the public and workers from normal decommissioning operations and from postulated accidents. The safety analyses utilize established data and methodology to estimate the various factors required, such as release mechanisms, dispersion pathways, and exposure modes of the released materials.

54 Murphy and Holter (1980)

Little information is currently available on the hazardous chemical content of LLW waste trenches. The migration of hazardous chemicals is a very serious concern, and an environmental analysis of the impact of hazardous chemical migration from LLW burial trenches should be undertaken in the future.

55 Rotow et al. (1979)

EPA's attitude here is that a risk is acceptable to society if it exists and if nothing has been done about it: a simplistic attitude, since most risks in modern technological systems have never been explicitly reviewed for acceptability and are not well understood. In any event, very fundamental considerations show that the existence of a risk about which nothing has been done does not mean that the risk is acceptable to society.

56 Lester et al. (1981)

The availability of data is a large concern. Many existing models far exceed data availability and their complexity is wasted since many features are not used. Models used in this study were chosen to maximize use of available data and avoid features which could not be used at present or in the foreseeable future because of lack of data.

A.7.1 Assessment Uncertainties

1 USEPA (1977b)

Should remedial measures be preplanned to contend with accidents at a deactivated/decommissioned low-level waste site, or, because of the nature of the waste and uncertainty of institutional stability in the future, should this approach be avoided?

2 USEPA (1978)

A waste disposal risk assessment should be performed to such a time as the risk to an individual becomes statistically insignificant or the uncertainties in make results meaningless.

3 USEPA (1978)

An adequate risk assessment should consider the quantity and persistence of the waste, and examine the projected effectiveness of alternative methods of control. An adequate risk assessment should also consider the probabilities of releases due to failures of controls and the uncertainties in all of these evaluations.

4 USEPA (1981e)

Given the absence of very long-term data, what confidence can one expect that a particular waste-management technique will, for a long period of time result in the predicted rate or concentration of air (gaseous) emissions (from waste-burial sites)?

5 USEPA (1981e)

What factors are most likely to undercut the accuracy of a prediction about environmental exposures (to disposed waste)?

6 USEPA (1981e)

What degree of confidence can one obtain in predicted environmental exposure (to disposed waste)?

- 7 Not enough is known at present about either the intrinsic toxicity of the various chemical constituents of LLW's or how they break down under different disposal conditions to quantify their hazard, which can be done for radioactive species. USDDE (1981b)
- 8 Are the calculational models that have been developed and used for estimating the radiation hazards from LLW disposal due to: (1) inhalation of dust by a reclaimer, (2) well water reclamation events, (3) direct gamma exposure, (4) atmospheric releases of contamination, (5) groundwater migration, (6) ingestion of food produced on a disposal site, and (7) surface erosion reliable and accurate enough to provide a sound basis for estimating the radiological impacts from near-surface disposal of FUSRAP waste? Adam and Rogers (1978)
- 9 The ratio of calculated/measured dose rates from evaporator plume releases for Sr-90 and Cs-137 are 5 and 1/5, respectively. The ratio of calculated/measured trench water concentrations from surface water transport for Sr-90 and Cs-137 are 4 and 10, respectively. These results suggest that calculated dose rates should be regarded as order-of-magnitude estimates, and that the estimates obtained by means of the analysis used in HUREG 0456 (Adams and Rogers (1978)) are not necessarily conservative, i.e., both overestimates and underestimates can occur. Adam and Rogers (1978)
- 10 In some instances assumptions are made that may not be conservative. Examples of possible nonconservatism are the assumption that corrosion of slit trench canisters and of the stainless steel components inside the canisters is minimal during the 200-year period of administrative control site, and the neglect of the effect of chelating agents in increasing the mobility of certain radionuclides. Such assumptions are made because of the inadequacy of the data base that would lead to meaningful quantitative results. Murphy and Holter (1980)
- 11 There are no well established models for treating overland flow. Murphy and Holter (1980)
- 12 The calculated maximum annual doses are based on the ICRP Publication 2 and the ICRP Publication 10A metabolic models, the ICRP Task Group Lung Model, and standard man parameters values. To the best of our knowledge, there are no reported assessments of the accuracy of dose calculations using these models and parameter values. Dose results are presented with no indication of the error associated with their use. Present insights into the degree of uncertainty involved are very limited and qualitative. Murphy and Holter (1980)
- 13 Many uncertainties exist in the parameter values used with the HMT model to simulate radionuclide migration via the groundwater pathway. Order of magnitude uncertainties exist in values for soil permeability, dispersion coefficients, distribution coefficients (Kd), and leach times. Murphy and Holter (1980)
- 14 Little attention has been given to the verification of transport models by field tests at existing sites. In part, this is because of the lack of an appropriate experimental apparatus for monitoring waste burial sites to assess the influence of environmental factors on radionuclide migration rates. Murphy and Holter (1980)
- 15 Public confidence in any radioactive waste disposal system will not be created by substituting mathematical modelling exercises that are impossible to validate for objective and verifiable design criteria. "Engineering judgement," that is, best guesses of modelling assumptions, and model parameters, should not be substituted for collecting basic scientific data and conservatively applying these data. On the other hand, by applying the philosophy of defense-in-depth, and insuring that the test of each component against its independent criteria can be validated with basic scientific data, public confidence in waste disposal systems should be improved. Management of uncertainty through application of defense-in-depth is a better way to proceed than an exclusive reliance on modelling. Cochran et al. (1979)
- 16 Because the analyses that were used in developing the classification system are consequence rather than risk analyses, the use of a 500 mrem per year exposure restriction for the maximally exposed individuals is considered to be conservative. We chose to use consequence rather than risk analyses because of the difficulties in assigning probabilities to the numerous events that can take place over the many years involved (risk equals probability times consequence). This is particularly true when dealing with generic disposal rather than waste and site specific disposal. Adam (1979)
- 17 Even though the analyses of the 28 cases cannot either substantiate or invalidate the meteorological and/or cow-milk models used, certain interesting observations can be made. These observations indicate that precipitation scavenging is a primary mechanism in the environmental transport of radioiodine and should be considered in any modeling of the air-grass-cow-milk pathway. Erb (1979)
- 18 In choosing and adapting existing models the principal criteria were:
 . Availability (quantity and quality) of data.
 . Convenience of existing model application (e.g., machine compatibility, running time, core storage, etc.).
 . Verification/validation runs available.
 . Compatibility with other subprograms.
 . Compatibility with objectives and scope of this project. Emphasis in choosing models was on "sufficient" rather than "best". The search for the "best" model involves extensive search and exhaustive comparison of which many model may do the job needed. A sufficient model needs only to meet the basic requirements and be reasonably efficient. Lester et al. (1981)
- 19 Water path sensitivity interactions were aquifer water travel time with nuclide solubility, aquifer water travel time with water body turnover flowrate and nuclide solubility with water body turnover flowrate. The interactions of solubility with travel time or water body turnover are very significant. It means that reasonable site resistance precludes any need to know solubility (nuclides could just as well be in solution) or also that high dilution rates in a body destroys significance of solubility. Perhaps, the need for better understanding of solubility is not always as necessary as might appear. Lester et al. (1981)

Some variables showed insensitivity. In the air path the layering of the solid column was found to be insignificant indicating that the geology of the soil column may not need to be defined in great detail but rather averaged properties could be used. Total column depth causes a pure delay in the output (with nuclide decay superimposed). The population distribution in distance was also relatively insignificant. That is, closeness to the site had little effect for airborne transport. In the water path dispersion in the aquifer had little effect on the results. Since dispersion coefficients are difficult to determine, this is fortuitous.

In the sensitivity study, a large number of independent variables were grouped to reduce the total number of inputs to the sensitivity testings. While this reduces the resolution, an attempt was made to group things that naturally track together, such as wind and dryness, soil size and loft percent, cows per acre, and beef cattle per acre, and so forth. Other values were held constant when it was clear that the output would be proportional to those values (for example, total population). The result was a set of 16 variable groups. Using standard fractional factorial techniques and Analysis of Variance, a test matrix of 648 air path and 144 water path cases was used in the systems model and analyzed for main effects and significant interactions. Interactions represent significant effects observed for one at a high or low level of the other. Some variables were found to act like switches in the model. At one level, they would reduce doses to zero while at a slightly different level would result in measurable results. These were adjusted to "turn on" the problem. In a range where such variables "turned-on" the problem, the effect of their value was insignificant. In the water path switch-like variables were rainfall, aquifer Kd, aquifer water travel time (length divided by flow rate), soil column Kd and nuclide solubility. In the air path switch-like variables were rainfall, nuclide solubility, site wind resistance (shelter and field angle to wind) and soil column Kd.

LWR release scenarios were developed by specifying the waste management activity phase, the initiating events, package types properties of the waste, vehicle condition, source category of the waste, and entry pathways. Activity phases are: packaging, transportation, unloading (arrival, handling), burial (replacement, uncovered wastes, backfill), repackaging, post-burial (administrative control, limited public use). Initiating events are chronic (direct radiation, atmospheric release, site contamination), natural events (rain/flood/wind), operational (container rupture, waste spill, fire, or explosion), and intrusion events (theft, animals). Waste properties include solubility and wind dispersibility. Source categories include decommissioning waste and heterogeneous. The entry pathways are: aquifer, atmospheric, direct radiation, erosion, contamination spreading, and unsaturated zone flow.

A.7.2 Quantification: Risk Measures, Valuation, Comparisons

- 1 Should the procedure for rulemaking consider cost effectiveness analysis or risk/benefit evaluations? Should a dollar value be established for health-effect mitigation? USEPA (1981a)
- 2 Are the relative advantages of the geology of drier regions great enough to support the tradeoff between the reduced risks at such sites versus the increased risks and cost associated with the transportation of wastes to such regions? USEPA (1977b)
- 3 High-consequence waste-disposal events that do not have a probability of occurrence less than that for comparable high-consequence events accepted by society for similar productive technologies should not be considered acceptable. USEPA (1978)
- 4 Chronic risks that are not less than those for comparable high-probability circumstances acceptable to society should not be considered acceptable. USEPA (1978)
- 5 Waste-disposal risks having high probabilities of occurrence resulting in more than a chronic risk which could not be reduced by reasonable controls should be considered unacceptable. USEPA (1978)
- 6 Probabilities of individual risk for the persons at risk should be aggregated over the total population to determine population risk. USEPA (1978)
- 7 Should there be a discounting of risks to future generations? How could this be equitably accomplished? USEPA (1981c)
- 8 What relationship should be maintained between permissible levels of risk to health from radiation exposure and other regulated hazards of disease or accidents?
- 9 Public hazards should be analyzed in terms of integrated long-term dose commitment. Macbeth et al. (1978)
- 10 Probabilistic analysis should be made of comparative hazard of low probability/high consequence and high probability/low consequence events. Macbeth et al. (1978)
- 11 Public acceptance is a major concern: Acceptability of risk: Compatibility of low-level radioactive waste disposal with criteria for disposal of other hazardous wastes. Consistent formulation and assessment of risks from radiation. Comparison of risks from other energy source wastes. Macbeth et al. (1979)
- 12 In combining injuries and fatalities to attain impact, fatalities were weighted ten times as heavily as injuries. (See Macbeth 1979, Table 3.2)

- 13 Macbeth et al. (1979)
The public as well as much of the scientific community appear inexperienced in assessing risks, [and, e.g.] in distinguishing [between] consequences and risks.
- 14 Macbeth et al. (1979)
Engineering improvements, e.g. in weather shielding, may offer risk/cost/benefit tradeoffs against transportation costs and risks.
- 15 USHRC (1981a)
The public exposure limits proposed by the NRC are given as annual maximum doses, whereas a common view is that the hazard of an activity should be measured by the total dose commitment attributable to that activity.
- 16 Murphy and Holter (1980)
To determine release conditions for a decommissioned LLH burial ground this study uses the concept of the maximum annual dose to an organ of reference of a maximum-exposed individual. The maximum-exposed individual is assumed to live and work on the decommissioned site, to eat all of his food from crops and animal products grown on the site, and to drink water from a well drilled on the site.
- 17 Murphy and Holter (1980)
As shown in Table 13.4-2, the option of relocating an entire trench offsite could result in two to three nonradiological injuries. For no cases would a fatal injury be expected, and for the other options even the probability of nonfatal injury is slight. However, relocating 100,000 to 200,000 cubic meters offsite (truck transport assumed), about 12 to 24 reference site trenches, would carry an expectation of from one to three fatalities.
- 18 Hebert et al. (1978)
The technical community tends to accept risk estimates at face value. In contrast, the general public often perceives the outcomes of an event to be more important than the probability. This may be due to the fact that the public is familiar with Murphy's Law: If something can go wrong, it will go wrong. Thus, probabilities are often perceived to be less meaningless than outcomes. However, it is not only the general public that considers outcomes to be more important than probabilities in certain situations. This often occurs in the world of business and industry, and a good example is provided by the nuclear area. Insurance companies would not insure nuclear reactors for unlimited liability because they lack a data base for actuarial calculations and because one large accident, regardless of how improbable the accident was, could ruin the insurance companies.
- 19 Rotow et al. (1979)
Protection requirements (for people and for the environment) should not be based primarily on assessment of risk to individuals and populations; rather, they should be based on societal evaluations of assessments of risk to individuals and populations.
- 20 Rotow et al. (1979)
EPA's attitude here is that a risk is acceptable to society if it exists and if nothing has been done about it: a simplistic attitude, since most risks in modern technological systems have never been explicitly reviewed for acceptability and are not well understood. In any event, very fundamental considerations show that the existence of a risk about which nothing has been done does not mean that the risk is acceptable to society.

- 21 Haxey (1979)
The following principles might better serve [i.e., better than comparison to natural background or than the NRC's criteria] as guidance in the formulation of social policies for radiation health protection:
(1) Any involuntary risks imposed by social policies for radiation protection must be congruent with, must not be in excess of, and may be reasonably less than, those involuntary risks imposed by the wide variations in naturally occurring toxic elements and harmful effects from our natural environment.
(2) There must be evidence that basic goods and essential benefits cannot be more satisfactorily obtained through other alternative means which entail fewer risks.
(3) The basic goods and essential benefits must be demonstrated or virtually assured, and they should outweigh the possibility of basic harm to human well-being.
- 22 USHRC (1981b)
The reference facility site minimally meets all of the site suitability requirements set out in Chapter 5. The facility is also assumed to be operated in compliance with minimum radiation safety practices required by provisions of 10 CFR Part 20. Although the facility is assumed to comply with the NRC Branch Technical Position on Site Closure and Stabilization (Appendix I), no special effort is assumed regarding the waste form or design and operational practices to ensure long-term site stability. Several design and operational improvements directed at stability that have been instituted at some existing sites have not been assumed for the base case site (e.g., vibratory compaction of backfill material). This has been done to establish a base case level of long-term costs and radiological impacts against which measures to improve site performance, achieve greater site stability, minimize radiological impacts, and to ensure adequate funding can be assessed. The facility is described in detail in Appendix E. A brief description follows.
- 23 USHRC (1981b)
As discussed in Appendix D, the reference waste volume distribution is generated through averaging all the waste volumes assumed to be generated in each of the 36 streams for each of the four regions, and normalizing these volumes to one million m³ of waste for waste spectrum one. This allows the effects of alternative waste spectra and alternative disposal facility designs and operating practices to be compared on a common basis.
- A.7.3 Specific Risk Statements
- 1 Macbeth et al. (1978)
LLH transportation risks are unlikely to be large.
- 2 Macbeth et al. (1978)
Immunity to sabotage should be ensured.
- 3 Macbeth et al. (1978)
Non-routine hazards are a very important consideration if the consequence is large, but otherwise are unlikely to be important.
- 4 Deichman (1979)
Evaluations should be made of the potential hazard from contaminated objects that may be interesting or useful artifacts and procedures developed to provide security against their removal.

- 5 The hazard to the general public from current LLW packaging and disposal practices is extremely small. USDOE (1981b)
- 6 The hazard potential for waste should be expressed in terms of radioactivity per unit volume at the time of disposal. Adam and Rogers (1978)
- 7 The concerns and issues associated with the disposal of coal ash might be used as a measure for gauging the seriousness of concerns and issues associated with the disposal of FUSRAP waste. The ratio of the coal-ash/mill-tailings radon fluxes range from 0.001 to 0.1. Adam and Rogers (1978)
- 8 Non-radiological occupational injury and fatality projection for disposal activities were based on [National Safety Council] statistics for comparable industries. Macbeth et al. (1979)
- 9 Risks for rail transport [of LLW] are slightly less than for trucks but result in the same order of impacts for the various alternatives. Macbeth et al. (1979)
- 10 Sabotage and intrusion into the waste during 150 year institutional control period were not included in Macbeth's analysis, assuming similar effects on all alternative disposal methods. Macbeth et al. (1979)
- 11 Non-radiological impacts from constructing an SLBF on a site which is undesirable for other uses and remote from population centers would be small. Routine hazards to workers would be comparable to those in general construction and in surface mining. Macbeth et al. (1979)
- 12 In combining injuries and fatalities to attain impact, fatalities were weighted ten times as heavily as injuries. (See Macbeth 1979, Table 3.2) Macbeth et al. (1979)
- 13 Transportation risks are often based on WASH-1238 (1972), which may be out of date. Macbeth et al. (1979)
- 14 Experience in interim storage of wastes provides some basis for assessment of waste handling accidents. Macbeth et al. (1979)
- 15 Inhalation doses to decommissioning workers are expected to be negligible for site stabilization and long-term care, since these operations do not normally involve direct contact with buried waste or contaminated soil. However, waste relocation operations may involve the generation of dust containing radioactive particulates, and these operations could result in substantial inhalation doses. The use of respiratory equipment to minimize inhalation doses from those operations which have potential for the generation of airborne radioactivity, is assumed. Murphy and Holter (1980)
- 16 Public confidence in any radioactive waste disposal system will not be created by substituting mathematical modelling exercises that are impossible to validate for objective and verifiable design criteria. "Engineering judgement," that is, best guesses of modelling assumptions, and model parameters, should not be substituted for collecting basic scientific data and conservatively applying these data. On the other hand, by applying the philosophy of defence-in-depth, and insuring that the test of each component against its independent criteria can be validated with basic scientific

data, public confidence in waste disposal systems should be improved. Management of uncertainty through application of defence-in-depth is a better way to proceed than an exclusive reliance on modelling.

- 17 Because of the difficulty and cost of obtaining materials in such a remote location, the people of Bonty appeared reluctant to part with any item that could have a salvage value. Many residences were observed to have accumulated stockpiles of salvageable items including lumber, tires, automobiles, appliances, and a myriad of other materials. Plywood shipping containers were routinely disassembled to salvage the wood. Numerous radium dial objects, and contaminated tools of all kinds were diverted. It was apparent that any item of practical use or of just human interest had the potential for being diverted. Henslawski and North (1979)
- 18 External sources of exposure include cosmic rays, together with the radionuclides they produce, and the primordial radionuclides in the earth. Internal exposure from natural radionuclides inhaled or ingested via foods and drinking water augment that external exposure appreciably (e.g., potassium-40 adds 17 mrem.) Large segments of the population in the United States receive natural external radiation doses varying from 41 to 105 mrem per year simply because of geographic location. Variations in natural exposure to thorium in monazite sands along the southeastern coast of India range from 130 mrem to 2,800 mrem; while on the coast of Brazil, exposure ranges from 90 to 2,800 mrem with an average of 550 mrem per year. There is no scientifically established evidence, despite contrived attempts to prove it, that there are basic harms to those so exposed. Haxey (1979)
- 19 A potential class of pathways from the LLW operations to the public is by means of deliberate actions on the part of operating personnel. The most obvious of these is sabotage. There has already been an instance of sabotage-related activity at the Surry nuclear power station. A related activity is the theft of LLW from the site with malicious intent for political or other reasons. Because of the form of the materials and the relatively low levels of radioactivity, low-level wastes are considered unlikely targets for sabotage. Even if subjected to criminal acts, no major hazard would result. Lester et al. (1981)

A.7.4 Long-Term Future

- 1 Should the rulemaking bases consider limits on planned individual and population risk, both for present and future generations? USEPA (1981a)
- 2 Should remedial measures be preplanned to contend with accidents at a deactivated/decommissioned low-level waste site, or, because of the nature of the waste and uncertainty of institutional stability in the future, should this approach be avoided? USEPA (1977b)
- 3 Considerations of risks to future generations should be included in the bases for low-level waste disposal rulemaking. USEPA (1977b)

- 4 Low-level wastes should be disposed of in such a way that the risk to future populations should be no greater than we are willing to accept ourselves. USEPA (1977b)
- 5 Risks to future generations due to our radioactive waste should be no greater than those accepted by the current generation (as expressed in its standards and regulations for radioactive waste). USEPA (1978)
- 6 How can we ensure that all risks are included in a risk assessment that is based (solely) on calculations and judgement? USEPA (1978)
- 7 Are there enough reliable data available to perform a waste-disposal risk assessment with certainty? USEPA (1978)
- 8 A waste-disposal risk assessment should estimate, to the extent possible, (uncertainties) in risk. USEPA (1978)
- 9 If considerations of adverse effects (of waste disposal) for a long period might result in choosing a more effective disposal technique, then general estimates should be made for more than 1,000 years into the future. USEPA (1978)
- 10 An adequate risk assessment for radioactive wastes should estimate the potential health effects on humans for 1,000 years. USEPA (1978)
- 11 Should there be a discounting of risks to future generations? How could this be equitably accomplished? USEPA (1981e)
- 12 Given the absence of very long-term data, what confidence can one expect that a particular waste-management technique will, for a long period of time result in the predicted rate or concentration of air (gaseous) emissions (from waste-burial sites)? Macbeth et al. (1979)
- 13 Among the expected radiological impacts of a "reference" SLRF, food pathways yield the most significant long-term effects, while accidental airborne releases lead to the largest short-term effects (see Macbeth 1979, Table 3.6). USHRC (1980a)
- 14 As stated, the staff considers that conservative design of tailings disposal programs and careful siting of disposal impoundments can provide reasonable assurance that the tailings will remain isolated for very long periods of time. However, the very long-term performance of tailings isolation (that is, several thousands of years into the future and beyond) will be governed by climatic and geologic forces which cannot be predicted precisely. Therefore, there is uncertainty about very long-term effects. However, radioactivity in the tailings, unlike high level nuclear waste, poses a chronic as opposed to an acute hazard. Long and sustained exposure to radioactivity in the tailings pile would be required to produce detectable adverse effects. If degradation or failure of isolation were to occur, it would not lead to catastrophic radiation effects. There would be ample time to take corrective action.
- 15 The standards require a reasonable expectation that the disposal methods will be effective for at least one thousand years. USEPA (1980d)
- 16 The historical background on radiation standards presented above illustrates two aspects of the public's attitude toward radioactive contamination: Cochran et al. (1979)
1. No amount of radioactive contamination is "acceptable." This was the public message that brought about the Atmospheric Test Ban Treaty and the demise of the Plowshare Program for the peaceful uses of nuclear explosives.
2. The effects of radiation on future generations are of prime importance and can not be discounted. This is illustrated not only by the ATB Treaty and Plowshare ban but also by the public concern over long lived nuclides and the tailing piles.
- 17 Because the analyses that were used in developing the classification system are consequence rather than risk analyses, the use of a 500 mrem per year exposure restriction for the maximally exposed individuals is considered to be conservative. He chose to use consequence rather than risk analyses because of the difficulties in assigning probabilities to the numerous events that can take place over the many years involved (risk equals probability times consequence). This is particularly true when dealing with generic disposal rather than waste and site specific disposal. Adam (1979)
- 18 Caution is dictated not by the magnitude of the risks but by their long duration. The principal risks extend for about a thousand years, and the presence of actinides in the wastes adds a very small continuing risk for millions of years. In this respect, however, nuclear waste disposal is not entirely unique. Elevated CO₂ concentrations in the atmosphere, once established, will persist for many hundreds of years, and over this extended period could have devastating effects, if the hypothesis of climatic changes due to CO₂ accumulation proves correct. National Acad. of Sci. (1979)
- 19 If our descendants are sophisticated and "radiation conscious" they would find detection of the source to be very simple and correction of the condition equally simple. If they are not, it is likely to be because their technology has so regressed that they are subject to much more pressing dangers. National Acad. of Sci. (1979)
- 20 One tailings and low-level radioactive waste from the nuclear industry need a sound program of environmental protection to ensure that they do not present significant health risks to the public. Since even the worst-case risks from those sources are quite low, the steps required should be based on the most probable values of costs and risks, rather than on the most conservative possible assumptions. (1) (1) Statement 5-12, by J.P. Holdren: I disagree. Conservation is particularly appropriate when the potential victims are in future generations, as is the case with tailings and low-level wastes. National Acad. of Sci. (1979)

A.8 WASTE

- 1 The increased depth of disposal [in IDB as compared to SLB] may be especially important [when] formation of gases containing radionuclide is a concern. Daichman (1979)
- 2 Issues relating directly to waste classification which can be evaluated on a quantitative basis using existing data are: waste classification, reducing waste volumes, waste packaging, environmental release, storage for decay, interim storage, and disposal options. USDOE (1981b)
- 3 Industrial generators are considered to be all commercial waste producers that are not power plants or institutions. USDOE (1981b)
- 4 There are seven fuel-fabrication facilities in the U.S. that produce fuel for nuclear power plants (in PA, NC, SC, VA, MO, CT). A full process fuel fabrication plant annually generates about 1,133 cubic meters of LLW that is shipped offsite for SLB. USDOE (1981b)
- 5 Most of the LLW produced through government activities (energy research and military programs), about 50,000 meters a year, is disposed of at government-owned and operated sites, [of which] there are fourteen in the U.S. USDOE (1981b)
- 6 A reasonably realistic projection of total non-government-generated LLW for the period 1980-2000 suggests that perhaps five new sites would suffice to accommodate this cumulative waste. The total volume of this LLW is 5 to 10 times that estimated (600,000 cubic yards) for FUSRAP generation. USDOE (1981b)
- 7 Chemical hazards of wastes in SLB can be due to constituents whose degradation can be enhanced by appropriate burial conditions, whose lifetime is essentially infinite, or which synergistically increase radiological hazards. EPA regulations require a 30 year post-closure control period for hazardous wastes. USDOE (1981b)
- 8 The major deficiency [of 10 CFR 61] is a paucity of information regarding the handling of chemical hazards. USDOE (1981b)
- 9 With solid forms, problems have been associated with the presence of organic chelating agents in the buried waste. Jacobs et al. (1980)
- 10 Currently, over 60,000 cubic meters of commercial LLW are disposed of at commercial sites and about 35,000 cubic meters generated in defense programs are disposed of at DOE sites. Macbeth et al. (1979)

- 11 Reference waste volumes and characteristics [in the NUREG/CR-0630] were selected to be typical of LLW to be disposed of in the future, and may not be typical of any single class of radioactive waste but represent averages over a broad spectrum. Macbeth et al. (1979)
- 12 It may be advantageous to render the waste unattractive to a potential reclaimer to enhance protection after institutional controls have been relinquished. Macbeth et al. (1979)
- 13 IDB has also been suggested for disposal of radioactive uranium mill tailings. (FBDU-211, May 1978) Macbeth et al. (1979)
- 14 Although the Commission has no direct statutory authority over naturally occurring and accelerator-produced radionuclides the evaluation of any specific disposal site will include consideration of the total impacts from all waste disposed of at the site, including byproduct, source, and special nuclear material, and naturally occurring and accelerator-produced material. USNRC (1981a)
- 15 Engineered storage could be provided for wastes likely to require relocation at some future time. Murphy and Holter (1980)

A.8.1 Characterization and Classification

- 1 Should the basis of environmental radiation protection rulemaking be established generically to address all forms and types of radioactive wastes? USEPA (1981a)
- 2 Should rulemaking be based on waste categorization, and if so, by what methodology (activity, half-life, waste form, etc.)? USEPA (1977b)
- 3 Does segregation of wastes by half-life, activity, and/or other characteristics provide a net advantage? USEPA (1977b)
- 4 A waste disposal risk assessment should consider physical and chemical characteristics as well as persistence of waste. USEPA (1978)
- 5 When is the packaging material for radioactive waste considered a radioactive waste? USEPA (1978)
- 6 Should rulemaking considerations address activated and/or absorbed radioactive materials that are not currently addressed by standards-setting agencies? USEPA (1978)

7	How do rule-making considerations specifically address the definition of past, present, and future radioactive wastes?	USEPA (1978)	nuclear fuel, or byproduct material as defined in section 11c (2) of the Atomic Energy Act of 1954. [Pub.L. 96-573, Sec.2(2)]	
8	Should there be more categories of radioactive wastes?	USEPA (1978)	20 NRC must develop a simple LLW classification system based on total hazard which includes upper and lower concentration bounds.	USDOE (1980c)
9	Should there be distinctions between high and low-level (and naturally occurring radiation) waste in defining radioactive waste?	USEPA (1978)	21 The waste classification scheme that is recommended is one that is based on total hazard.	USDOE (1980c)
10	Should redistributed naturally occurring radionuclides that increase human exposure be considered radioactive waste?	USEPA (1978)	22 Some LLWs have such small levels of radioactivity that they pose no significant hazard to the public. It should be so designated in an appropriate classification category. Environmental release is recommended as a safe disposal option for these wastes.	USDOE (1980c)
11	Is the rationale for the classification of wastes on the basis of (pre-existing) natural levels of radiation reasonable?	USEPA (1978)	23 It is now generally accepted that LLW cannot contain more than 10n Ci/g of TRU nuclides.	Lipton (1981)
12	Do current regulations (rules) provide assurance that radioactive materials that are restricted from routine release to the biosphere will be properly classified as waste?	USEPA (1978)	24 Development of instrumentation for in-situ physical chemical characterization of buried waste (would be quite desirable). However a high cost/benefit ratio and restricted utility is probable.	Deichman (1979)
13	When is radioactive waste material no longer considered radioactive by virtue of (the) decay process?	USEPA (1978)	25 The most detailed classification of LLW is contained in regulations governing transportation (49 CFR 100-177).	USDOE (1981b)
14	How could the term "radioactive waste" be more simply defined?	USEPA (1978)	26 Voters in one state recently passed an initiative to ban the disposal of low-level nonmedical wastes from out of state. This classification by source has national impact on waste management practices.	USDOE (1981b)
15	Since waste discharges (migrations) are generally episodic and short-term in nature, designation of hazardous waste should be limited to materials exhibiting acutely toxic effects.	USEPA (1980b)	27 All operating sites specify the segregation of types of waste and the packaging for each.	USDOE (1981b)
16	Substances should be designated as hazardous on a regional basis, since water chemistry may vary at differing locations.	USEPA (1980b)	28 Five alternatives for waste classifications are (1) continue present practice, (2) classify [all] in one category, (3) classify by source, (4) classify by radiological hazard, (5) or classify by total hazard.	USDOE (1981b)
17	LLW classification should be based on total hazard, e.g., chemical toxicity as well as radioactivity.	Levin (1980)	29 The lack of comprehensive [waste] classification system would hinder formation of interstate compacts, thus impeding development of regional disposal sites.	USDOE (1981b)
18	Identification and study of organic materials that influence release and migration of radionuclides from the disposed wastes (is desirable).	Levin (1980)	30 General trash of very low activity might be declared legally non-radioactive and could be buried in sanitary landfills.	USDOE (1981b)
19	The term "low-level radioactive waste" means radioactive waste not classified as high-level radioactive waste, transuranic waste, spent	USDOE (1980c)	31 Classification by radiological hazard would be based on hazards all along the path of LLW management: handling, packaging, transportation, and ultimate disposal.	USDOE (1981b)

- 32 USDOE (1981b)
A [waste] classification scheme based on total hazard would be similar to classification based on radiological hazard, but would also take into account carcinogenicity, pathogenicity, chemical and biological toxicity. The ultimate handling, transportation, and disposal criteria would be based on the additive, and possibly synergistic, hazards of the waste.
- 33 USDOE (1981b)
Classification by total hazard is deemed desirable by the states, which [should] enhance development of regional compacts and disposal sites, and it should achieve greater protection of the public than any alternative classification scheme. However, costs of waste management and disposal would increase substantially, and regulation development and enforcement would significantly impact on regulatory agencies.
- 34 USDOE (1981b)
The issue of environmental releases deserves a high priority. Central is the lack of consistency between current requirements for disposal of LLW in solid form and regulations allowing certain concentrations of liquid and gaseous radioactive materials to be released to the environment.
- 35 USDOE (1981b)
Current practice does not allow the release of solid radioactive waste into the environment. Items with surface activity can be decontaminated and recycled, but items with internal contamination from neutron activation must be shipped to disposal sites whatever their potential of hazard.
- 36 USDOE (1981b)
The American College of Nuclear Physicians has recommended that all federal agencies adopt the DOT definition of radioactive material. This would expedite handling of wastes now unnecessarily defined as radioactive.
- 37 USDOE (1981b)
Not enough is known at present about either the intrinsic toxicity of the various chemical constituents of LLW's or how they break down under different disposal conditions to quantify their hazard, which can be done for radioactive species.
- 38 USDOE (1981b)
Disposal matched to the nature of the waste should be more acceptable than SLB because it implies a more rational approach than use of a single generic technique for a heterogeneous mix of materials and hazards.
- 39 USDOE (1981b)
In disposal according to the nature of the waste, any components of the waste separated out as too hazardous for SLB will almost surely lead to disposal and public acceptance situations similar to those for HLW. It may then be appropriate to consign some LLW to HLW repositories.
- 40 USDOE (1981b)
The regulatory framework requisite for disposal according to the nature of the waste will not be fully established for several years.
- 41 Jacobs et al. (1980)
Knowledge of the radiological, chemical, and physical characteristics of the contents of waste packages is required to facilitate the optimum disposal of solid radioactive wastes. It is difficult to describe adequately the heterogeneous mixture of materials that make up the waste packages to be buried (USGS75). However on-site measurements of radioactivity are currently considered economically prohibitive (Gat75).
- 42 Jacobs et al. (1980)
Waste form is an important factor in minimizing radionuclide releases. The mobility of liquid and gaseous wastes makes them undesirable waste forms for shallow land burial.
- 43 Jacobs et al. (1980)
The handling and disposal of waste radioactive material presents a potential for radiation exposure of operational personnel and a possible source of radionuclide release to the environment. The development and implementation of a safe waste disposal policy requires understanding of the extent of the potential hazards. Thus, the radiological, chemical, and physical characteristics of the contents of the waste packages must be known and recorded. To assure that future records are maintained adequately requires establishment of techniques for the accurate characterization of the waste upon packaging and techniques for the verification of waste character at the receiving site.
- 44 Jacobs et al. (1980)
The most thorough characterization of the waste can be made at the waste source. The waste producer should be aware of the types of information needed by the disposers, be equipped to make the necessary measurements in a heterogeneous mixture, and be motivated to be accurate in the characterization.
- 45 Jacobs et al. (1980)
In the absence of suitable characterization or verification of contents by the waste producer, waste characterization could take place at the receiving site. Waste properties which influence options for disposal should be measured. Thus, there is particular concern for long-lived radionuclides with high radiotoxicity, and radionuclides with high potential mobility. Methods to verify the physical characteristics of waste receipts and procedures for remedial action are needed.
- 46 Jacobs et al. (1980)
Further instrumentation research is needed for assay of TRU at the 10 nCi per gram level on waste packages.
- 47 Jacobs et al. (1980)
The critical radionuclides in waste should be identified on the basis of such factors as quantities, concentrations, radiotoxicity, environmental mobility and persistence. Potential acute and chronic release mechanisms should be identified and ranges established for their probabilities of occurrence for the time period the waste remains hazardous. Further work should describe and quantify the probable ranges of the rate of environmental transport and exposure for a broad spectrum of pathways. Systematic evaluations for the full chain of considerations would then identify those radionuclides and pathways which are likely to be most important so that emphasis can be placed on their quantification in subsequent research and development.

- 48 Jacobs et al. (1980)
Specific items related to waste records that need additional research and development emphasis include: (1) standardization of records; (2) verification of waste receipts; (3) development and appreciation of techniques to construct inventories from past operations.
- 49 Macbeth et al. (1979)
A typical LLW inventory (Macbeth 1979, Table 2.1) shows 90% of the waste to have low level radiation, totaling 1.2 Ci/m³, and 10% having higher radiation levels totaling 570 Ci/m³.
- 50 Macbeth et al. (1979)
[For a typical inventory of LLW], the only nuclide of significance for a direct gamma radiation after 150 years is Cs-137.
- 51 Healy (1980)
Limits for wastes disposed of in long-lasting containers should be lower, to control intruder doses, than for limits in which degradation and mixing with the soil can be expected. Note that the present regulatory trend of requiring containers as long-term barriers will accentuate the problem.
- 52 IAEA (1981)
The wastes should be characterized according to their radionuclide content, physical and chemical properties, and appropriate restrictions and burial procedures based on this information should be adopted.
- 53 USNRC (1981a)
In response to NRC advance notice of proposed rulemaking many commenters advocated a system for classifying or segregating LLW according to hazard, and the most often expressed disadvantage of any alternative disposal method was potential for increased cost.
- 54 USNRC (1981a)
Any waste which, after the 100 year period of institutional control, would cause exposure greater than 500 mrem to an inadvertent intruder is identified as class C intruder waste and must be protected by deeper burial (a minimum of 5 meters below grade) or an equivalent natural or engineering barrier.
- 55 USNRC (1981a)
For most alpha-emitting TRU, maximum allowable concentrations were calculated to be in the range of 10 nanocuries per gram. This conservative limit was retained because of its well-established achievability and a tendency toward more conservative assessment of hazards of certain transuranic nuclides.
- 56 USNRC (1981a)
NRC has not developed a classification of waste, based on the total hazard. The classification is based on radiation protection considerations. Other hazards presented by associated components of waste (e.g., chemical and biological hazards) are addressed by exclusion or treatment of certain chemical, physical, and biological forms of waste.
- 57 USNRC (1981a)
NRC recognizes the need for a "de minimis" classification of wastes, wastes which would be exempt from Part 61 and of no regulatory concern. Such exceptions should, however, be determined on a specific waste basis (as for tritium and C-14) and Part 61 will not establish a generic "de minimis" category for waste.
- 58 USNRC (1981a)
The regulation in this part [i.e., Part 61] do not apply to the disposal of high-level waste as provided for in Part 60 or byproduct material (as defined in 40.4(a-1)) as provided for in Part 40 and licensed material as provided for in Part 20.
- 59 USNRC (1981a)
Waste [here] means LLW containing source, special nuclear, or byproduct material that is acceptable for disposal in a land disposal facility. [Here] LLW has the same meaning as in the LLW Policy Act, i.e. is not classified as HLW, TRU, spent fuel, or byproduct material as defined in section 11e.(2) of the Atomic Energy Act.
- 60 USNRC (1981a)
Waste which does not contain enough activity to be of concern from the standpoint of migration and which decays to acceptable levels during the period that site is occupied is not required to be in stable form and is classified as Class A segregated waste.
- 61 USNRC (1981a)
Institutional control periods of up to 100 years permit the disposal of Class A segregated and Class B stable waste without special provisions for intrusion protection, since these wastes will decay during the 100 year period to levels that do not pose a danger to public health and safety.
- 62 USNRC (1981a)
Waste that will not decay to such [i.e., innocuous] levels within 100 years is designated as Class C intruder waste.
- 63 USNRC (1981a)
Class C waste must be buried deeper than other waste, or, if site conditions prevent this, protected by engineering barriers. The assumed effective life of these barriers is 500 years, and the maximum radionuclide concentration for all wastes must, in general, be such that at the end of the 500 year period no danger to public health and safety remains.
- 64 USNRC (1981a)
The disposal site shall be used exclusively for the disposal of radioactive wastes.
- 65 USNRC (1981a)
Class A segregated waste is waste that is segregated at the disposal site and disposed of with only minimum requirements on the waste form and characteristics, and (1) whose radioisotope concentration does not exceed the values shown in Column 1, Table I, [61.55 of 10CFR61] and whose physical form and characteristics meet the minimum requirements set forth in sec. 61.56(a).

- 66 USNRC (1981a)
Class B stable waste is waste that must meet more rigorous requirements on waste form to ensure stability after disposal and (1) whose radioisotope concentration exceeds the concentrations shown in Column 1 of Table I, sec. 61.55 of 10 CFR 61 but not those of Column 2, and (2) whose physical form and characteristics must meet the minimum and stability requirements set forth in sec. 61.56.
- 67 USNRC (1981a)
Class C intruder waste is waste that not only must meet more rigorous requirements on waste form to ensure stability but also requires special measures at the disposal facility to protect against inadvertent intrusion. (1) Its radioisotope concentrations exceed those shown in Column 2 of Table I, Sec. 61.55 of 10 CFR 61, but not those shown in Column 3. (2) Its physical form and characteristics meet the minimum and stability requirements set forth in sec. 61.56.
- 68 USNRC (1981a)
Waste [whose] radioisotope concentration exceeds the values shown in Column 3 Table I, of this section is not generally acceptable for near-surface disposal.
- 69 USNRC (1981a)
Minimum requirements for all classes of waste which is to be disposed of by near-surface burial include: (1) waste must be packaged and the waste form and packaging must meet all applicable transportation requirements of NRC (10 CFR 71) and DOT (49 CFR 171-179); (2) wastes must not be packaged for disposal in cardboard or fiberboard boxes.
- 70 USNRC (1981a)
10 CFR 61.56(a) (4)-(8) lists several minimum requirements for all classes of waste which pertain to non-radiological hazards that are unlikely to be significant in the FUSRAP wastes themselves. Requirement (3) pertains to liquids in wastes. These requirements may apply to wastes generated by remedial actions.
- 71 USNRC (1981a)
Stability requirements are intended to assure for at least 150 years that the waste does not degrade and promote disposal unit failure leading to water infiltration.
- 72 USNRC (1981a)
Waste must have structural stability, provided by the waste form, by processing to a stable form, or by disposal container or structure. A stable form will maintain its dimensions within 5% and its form under expected compressive load of 50 psi and other factors (e.g., moisture, microbial activity, radiation, and chemical effects, etc.)
- 73 USNRC (1981a)
NRC may, upon request or on its own initiative, authorize other provisions for the classification of waste on a specific basis; if, after evaluation of the specific characteristics of the waste, the disposal site, and method of disposal, it finds reasonable assurance of compliance with the performance objectives.
- 74 Murphy and Holter (1980)
To allow unrestricted release following the decommissioning of future burial grounds, it may be necessary to limit the type, quantity, and chemical and physical form of the radionuclides buried at these sites.
- 75 Murphy and Holter (1980)
The radionuclide Ra226 presents a unique problem in determining site release conditions and requires separate consideration. The Ra222 daughter is a noble gas and does not bind chemically or physically to the soil.
- 76 Murphy and Holter (1980)
Little information is currently available on the hazardous chemical content of LLW waste trenches. The migration of hazardous chemicals is a very serious concern, and an environmental analysis of the impact of hazardous chemical migration from LLW burial trenches should be undertaken in the future.
- 77 Shapiro (1981)
The low-level and transuranic wastes that have built up in the equipment during its lifetime are inventoried as D & D material. ...Already classified as such are ... an estimated 19.4 million cubic feet of former Manhattan Project and AEC facilities that recent surveys have found to be contaminated to some degree....
- 78 Roessler et al. (1979)
The naturally occurring uranium series radioactivity appearing in phosphate mining spoils and the waste and by products of beneficiation and chemical plant operations is for the most part contained in large volumes of relatively low radioactivity concentrations. The solution to management of materials and lands with radioactivity levels that do not meet unrestricted use criteria consists of (1) restricting land and materials use and/or (2) selective in situ placement of higher radioactivity materials in a manner that meets criteria for the desired use.
- 79 Roessler et al. (1979)
In late 1978, proposed hazardous waste regulations of the U.S. Environmental Protection Agency designated overburden and slimes from phosphate surface mining, gypsum from wet-process phosphoric acid production and slag from elemental phosphorus production as hazardous solid wastes (US78).
- 80 USNRC (1981b)
Based upon the analyses in Chapters 4 and 3, there are two fundamental mechanisms to classify wastes for long-term hazard: (1) Consideration of potential hazard to an inadvertent intruder due to direct contact with the disposed waste; and (2) Consideration of potential hazard to an individual or a population from potential consumption or use of contaminated ground water.
- 81 USNRC (1981b)
NRC also recognizes that there are several other isotopes (e.g., thorium and radium) for which concentration limits should be developed. Others may also be identified. NRC plans to analyze development of limits for such radionuclides subsequently. In the meantime, some working concentration limits should be considered for isotopes not presently analyzed. For these, NRC believes a reasonable, yet conservative, approach would be following:
 . Use of values for Sr-90 for beta-emitting isotopes with little or no gamma radiation;
 . Use of values for Cs-137 for beta-emitting isotopes having significant gamma radiation; and
 . Use of values for enriched uranium (U-235) for alpha-emitting isotopes other than radium.
 For radium, no limits are established as of yet. NRC plans to further develop in the near future uranium, U-233, and other isotopes.

Given the wide range in potential hazards by LLW (e.g., chemical, biological, physical as well as radiological), NRC also initiated a study to examine chemical and other hazards associated with LLW and to examine if a quantitative method could be developed and applied for comparing radiological hazards with chemical hazards (Ref. 81). Based on the study results and current technical abilities to characterize potential effects of biological and chemically hazardous wastes and to make direct comparisons with potential radiological hazards, it is not technically feasible at this time to break down all the different hazards and to assign a hazard factor that represents some weighted index of hazard. In general, the site and other requirements being developed for radioactive waste should be adequate to cover other hazards.

Wastes which still contain appreciable activity after several hundred years (e.g., 500 years) would appear to more closely resemble high-level waste than what is usually considered to be low-level waste.

A.8.2 Packaging

When is the packaging material for radioactive waste considered a radioactive waste?

Regulations for disposal packaging should be added to existing packaging regulations for transportation.

The method of packaging for transportation of materials generated by decontamination, generally, either containerized or bulk [1] is a key issue affecting cost and schedule.

Packaging contaminated material [in] containers such as 55 gallon drums [leads to] costs for handling and transport [which are] three or four times greater [than those] for shipment by bulk transporters such as large-volume trucks or railroad cars.

Migration through groundwater must be considered [if] waste containers are designed for safety only during transportation and burial.

Use of standard packages containing compacted waste would permit efficient, modular stacking configurations which would alleviate many operational problems.

Criteria establishing type and form (including packaging) of waste appropriate for burial, depth and dimensions of burial trenches, and capping are needed to ensure suitable operational practice.

The most detailed classification of LLW is contained in regulations governing transportation (49 CFR 103-177).

All operating sites specify the segregation of types of waste and the packaging for each.

The hazard to the general public from current LLW packaging and disposal practices is extremely small.

In the new part 61 regulations, only general performance criteria will be given, [and] many different types of packaging may be developed to meet the criteria.

Leachability of radioactive materials from the package and from the site are not considered [by NRC] the main problem in terms of packaging. Physical stability of [the] waste package [is to be emphasized.]

Both NRC and DOT prefer state inspection and enforcement of federal regulations for waste packaging and transportation.

Issuance of a single set of [packaging] regulations for both transportation and disposal [of LLW] would have little effect on public health and safety.

The degree of compatibility of treatment and packaging required for disposal with packaging required by DOT regulations will affect whether disposal packaging is done by the generator or at the disposal site.

In general, waste packages are designed to provide containment of waste during transport to the burial site and during emplacement, but not for long term containment after disposal.

Attention needs to be given to the selection, design, and fabrication of waste packages. The use of standardized packaging would facilitate the development of improved shielding for containers and mechanized handling systems; both could reduce radiation during waste handling (Mu176).

Initially, hydrologic and geologic site characteristics were relied upon for waste containment. Packaging was provided to meet transportation requirements and for ease of handling, but not relied upon for containment.

Wastes must be emplaced in an orderly manner that maintains package integrity during emplacement and disposal.

A second waste retrieval program at INEL, the Early Waste Retrieval project was initiated in FY 1976 to investigate the problems associated with retrieval and repackaging of drummed and boxed TRU waste material that was buried between 1960 and 1963. The waste material and drums were found to be randomly distributed in the trenches. Virtually all the waste drums were severely rusted and otherwise badly deteriorated. Several of the drums contained liquids. In some cases, the liquids leaked from the drums during excavation. In all cases, the spread of contamination was confined within the DAC building.

The NRC had in mind at the time of the Advance Notice that the use of multiple barriers (natural and man-made, such as waste packaging form, and content) to radioactive waste movement and human contact with waste should be emphasized.

A.8.3 Treatment

- 1 Would there be any benefit derived from reprocessing the waste materials to recover minerals? USDOE (1981c)
- 2 Regulations and incentives should be combined to encourage optimal LLH treatment techniques. Levin (1930)
- 3 Could dilution of some FUSRAP waste be accomplished acceptably and bring activity concentrations to levels at which disposal would be allowable in sanitary land fills, in strip mines or abandoned quarries, or by ocean dumping less constrained as to packaging? Macbeth et al. (1978)
- 4 Low density waste can compact to produce voids in trenches, resulting in increased water infiltration, trench cap subsidence, and in some cases exposing the waste. Lipton (1951)
- 5 Compactors currently in use reduce waste volume by a factor of 2, although newer machines are up to a factor of 4. USDOE (1981b)
- 6 While volume reduction is hardly possible for most FUSRAP wastes, minimization of the volume of new waste generated by remedial actions is desirable. Procedures tending to achieve minimization should be adopted when cost/benefit assessment so indicates. USDOE (1981b)
- 7 The principle of dilution and dispersion has long been an accepted treatment for certain pollutants, and is the basis of current practice [when] releases of radioactive liquids and gases [is allowed]. USDOE (1981b)
- 8 It may be advantageous to render the waste unattractive to a potential reclaimers to enhance protection after institutional controls have been relinquished. Macbeth et al. (1979)
- 9 Waste conditioning (volume reduction, immobilization and packaging) should be required, as necessary, in order to reduce hazards and risks. IAEA (1981)
- 10 NRC recommends solidification of all radioactive wastes before shipment. Lash (1979)
- 11 The waste form should be effective against intrusion for several hundred years. After several hundred years (i.e., on the order of 500 years), most of the shorter-lived radionuclides will have decayed away, leaving the longer-lived radionuclides. The reduction in hazard after 500 years takes place at a much slower rate. Attempting to reduce intruder impacts through waste form beyond 500 years would really not accomplish much in the way of additional protection. USNRC (1981b)

A.9 TRANSPORTATION

- 1 Are the relative advantages of the geology of drier regions great enough to support the tradeoff between the reduced risks at such sites versus the increased risks and cost associated with the transportation of wastes to such regions? USEPA (1977b)
- 2 How will disposal operations effect transportation networks, including changes in traffic patterns and volumes? USDDE (1981c)
- 3 Regulations for disposal packaging should be added to existing packaging regulations for transportation. Levin (1980)
- 4 States should have the option of enforcing federal transportation regulations. Levin (1980)
- 5 Transportation routing rules should be set by the federal government with state participation. Levin (1980)
- 6 LLW transportation risks are unlikely to be large. Macbeth et al. (1978)
- 7 LLW transportation is regulated by DOT (packaging and handling, vehicle safety and maintenance), USCG (transport over water), DOD, DOE (shipment in noncivilian vehicles, aircraft, ships), and NRC (responsible for developing performance standards for large shipments). USDDE (1980c)
- 8 The method of packaging for transportation of materials generated by decontamination, generally, either containerized or bulk [1] is a key issue affecting cost and schedule). USDDE (1980b)
- 9 Packaging contaminated material [in] containers such as 55 gallon drums [leads to] costs for handling and transport [which are] three of four times greater [than those] for shipment by bulk transporters such as large-volume trucks or railroad cars. USDDE (1980b)
- 10 Transportation of contaminated material to a disposal site may be a significant factor in the cost of remedial action, and the major factor in the [transportation] cost is the distance for transport. USDDE (1980b)
- 11 To the extent consistent with other criteria, the site shall be selected with consideration given to location of waste generators, access to all-weather highway and rail routes, and access to utilities, (to minimize transportation costs and risks) Falconer et al. (1981)
- 12 Federal agency responsibilities are: USDDE (1981a)
NRC-establish performance and licensing criteria, approve licenses, regulate operation of LLHDF.
DOE-assist in proving state and regional solutions for adequate waste disposal, providing technical and other resources to the states.
DOT-regulate transportation of LLW, advise states on transportation requirements.
USCG-advise and assist other agencies and the states, provide objective technical assessments of geologic and hydrologic aspects of the sites.
- 13 The most detailed classification of LLW is contained in regulations governing transportation (49 CFR 100-177). USDDE (1981b)
- 14 Both NRC and DOT prefer state inspection and enforcement of federal regulations for waste packaging and transportation. USDDE (1981b)
- 15 Enforcement and inspection of transportation regulations could cost a state's agencies between \$50K and \$100K a year. USDDE (1981b)
- 16 [Establishment of standards for release of solid LLW] would reduce the cost of LLW transportation and reduce the number of highway accidents involving radioactivity. USDDE (1981b)
- 17 Generic cost analysis for SLB (Macbeth 1979) include costs for transportation, return on investment, money and profits, monitoring and surveillance for 150 years after closure. Transportation dominates in cost differences between eastern and western sites for all disposal concepts. USDDE (1981b)
- 18 The degree of compatibility of treatment and packaging required for disposal with packaging required by DOT regulations will affect whether disposal packaging is done by the generator or at the disposal site. USDDE (1981b)
- 19 Transportation costs and impacts dominate comparisons between eastern and western [disposal] sites, leading to the conclusion that regional sites are desirable. Macbeth et al. (1979)
- 20 Risks for rail transport [of LLW] are slightly less than for trucks but result in the same order of impacts for the various alternatives. Macbeth et al. (1979)
- 21 Transportation risks are often based on HASH-1238 (1972), which may be out of date. Macbeth et al. (1979)
- 22 Exposures associated with transportation of LLW are based on 1.8 x 10⁻⁵ manrem/car mile developed in HASH-1238. Macbeth et al. (1979)

- 23 Macbeth et al. (1979)
Actual charges for rail shipment of LLW from Rocky Flats to INEL and available data for truck shipping indicate costs for rail and costs for truck shipments to be of the same order of magnitude.
- 24 Macbeth et al. (1979)
Engineering improvements, e.g. in weather shielding, may offer risk/cost/benefit tradeoffs against transportation costs and risks.
- 25 USNRC (1980b)
To avoid proliferation of small disposal sites and to reduce perpetual surveillance costs, by product-material shall be disposed of at existing tailings disposal sites unless [it can be shown that] transportation costs and risks [or other countervailing considerations] clearly outweigh benefits of reduced surveillance obligations.
- 26 USNRC (1981a)
Minimum requirements for all classes of waste which is to be disposed of by near-surface burial include: (1) waste must be packaged and the waste form and packaging must meet all applicable transportation requirements of NRC (10 CFR 71) and DOT (49 CFR 171-179); (2) wastes must not be packaged for disposal in cardboard or fiberboard boxes.
- 27 USDOE (1981d)
Every kind of conflict of authority and interest which could arise over radwaste transportation is present, full blown, in the future disposal of spent fuel for the plants planned by Long Island Lighting Co. (LILCO). The only connection to the mainland is through New York City. NYC has banned transit through it of radioactive material, save under Certificate of Emergency from its Department of Health (which has been granted only for medical LLW and material). Brookhaven National Laboratory, which has a reactor, has identified ferrying across Long Island Sound as an option. New London, Conn., has enacted a ban similar to NYC's. LILCO and the federal government unsuccessfully sought an injunction against the NYC ban, the case was remanded for administrative action, and DOT found the ban to be inconsistent with its existing regulations. DOT is developing rules for routing of radwaste transportation. NRC's proposed rules (June, 1979) state that cities should be avoided where possible, but "avoidability" is open to dispute. If DOT's rules favor the NYC ban, LILCO will probably challenge in the courts. If DOT's rules favor LILCO, NYC will likely challenge DOT's constitutional right to rule on the matter at all. It may well take the U.S. Supreme Court to resolve the issues. The U.S. Coast Guard could also be involved, since it regulates transport over water, but that is not expected to be a significant complication.

A.10 SITE SELECTION

- 1 For site selection, what is the relative importance of environmental barriers such as geological strata versus engineered controls such as containers? USEPA (1977b)
- 2 Locations of radioactive waste disposal sites should be chosen so as to minimize environmental and human health impacts and, whenever possible, to enhance isolation over time. USEPA (1978)
- 3 Which, if any, of existing DOE and commercial LLW sites could be used for FUSRAP? (GAO is not convinced by DOE arguments.) Include possible re-opening of closed sites. Compt. Gen. of U. S. (1980)
- 4 [In] commercial site selection, the final decision [is] based on hydrogeological and economic factors. Macbeth et al. (1978)
- 5 New DOE LLW non-defense sites would also be licensed. USDOE (1980c)
- 6 [A] regional[compact] approach is preferable to federal preemption or 50 separate sites, based on considerations of cost, transportation, political issues, and health and safety factors.[HGA] USDOE (1980c)
- 7 Regional disposal sites for remedial action wastes is a preferred disposal option. USDOE (1980b)
- 8 The site selection process should include sufficient detailed information on site geology, hydrology, and meteorology to identify and evaluate all potential migration pathways. Lipton (1981)
- 9 The USGS has published a list of 17 characteristics of a proposed site which should be determined to decide if it is satisfactory. These include:
(1) Depth to water table, including perched water tables if present.
(2) Distance to nearest points of ground, spring, or surface water usage (includes well and spring inventory).
(3) Ratio of pan evaporation to precipitation minus runoff (by month for at least two years).
(4) Water table contour map.
(5) Magnitude of annual water table fluctuation.
(6) Stratigraphy and structure to base of shallowest confined aquifer.
(7) Baseflow data on perennial streams traversing or adjacent to site.
(8) Chemistry of water in aquifers and aquitards and of leachate from trenches. Lipton (1981)
- 10 Each generic disposal alternative has been analysed (Macbeth 1979) in terms of the following organization of considerations (which are referred to as evaluation factors):
Technical evaluation
Compatibility with the waste
Site selection factors
Safeguards
Environmental effects
Availability of technology
Sociopolitical implications
Public acceptance
Institution controls
Cost analysis
Cost estimates
Economic impact Macbeth et al. (1979)
- 11 Improved overall weather shielding, e.g. a weather shield building during trench filling and moisture barriers over the pits, could decrease the importance of adverse climatic conditions in site selection. Macbeth et al. (1979)
- 12 Sites for intermediate depth burial (IDB) are less plentiful than for SLB, but many areas of the country have more than adequate soil depth. Macbeth et al. (1979)
- 13 Many former strip mines are available [for IDB sites], where the recontouring [for erosion control] could be environmentally advantageous. Macbeth et al. (1979)
- 14 To avoid proliferation of small disposal sites and to reduce perpetual surveillance costs, by product-material shall be disposed of at existing tailings disposal sites unless [it can be shown that] transportation costs and risks for other countervailing considerations clearly outweigh benefits of reduced surveillance obligations. USMRC (1980b)
- 15 The optimum location for sites must take into consideration: conservation of energy in transport of radioactive wastes; fitness for a long-term disposal upon evaluation of geological and hydrological conditions; and density of waste production within the area in the predictable future. DiSibio (1980)
- 16 A suitable balance must be maintained among complementary characteristics in developing site selection criteria (e.g., precipitation, run off, erosion, infiltration, soil permeability, groundwater table level, and soil sorptive capacity) to assure containment of radionuclides. Certain site properties may be altered to improve site performance. Deichman (1980)
- 17 Although the Commission has no direct statutory authority over naturally occurring and accelerator-produced radionuclides the evaluation of any specific disposal site will include consideration of the total impacts from all waste disposed of at the site, including byproduct, source, and special nuclear material, and naturally occurring and accelerator-produced material. USMRC (1981a)

- 18 Waste [here] means LLW containing source, special nuclear, or byproduct material that is acceptable for disposal in a land disposal facility. [Here] LLW has the same meaning as in the LLW Policy Act, i.e. is not classified as HLW, TRU, spent fuel, or byproduct material as defined in section 11e.(2) of the Atomic Energy Act. USNRC (1981a)
- 19 Disposal site suitability requirements for land disposal other than near-surface [are for future rulemaking]. USNRC (1981a)
- 20 NRC may, upon request or on its own initiative, authorize provisions other than those set forth in sections 61.51 through 61.53 for the segregation and disposal of waste and for the design and operation of a land disposal facility on a specific basis, if it finds reasonable assurance of compliance with the performance objectives of Subpart C of this part. USNRC (1981a)
- 21 There should clearly be an exclusion zone around the facility, but a low population area is probably not necessary. Valore and Lawarsh (1978)
- 22 The shallow-Land Burial (SLB) Systems Model is being developed to provide a means of evaluating licensing alternatives in terms of site and operational parameters. The objective is to provide user-oriented code which makes efficient use of available data to perform dose assessment of various assumed scenarios. The SLB Model is designed from existing models and codes so that it is composed of previous established methodologies. The SLB Systems Model is not intended to be a risk model in the sense that all possibilities are considered and the most rigorous calculation made. The SLB Model is rather directed toward making comparisons of situations to weigh alternatives. A set of scenarios is being provided with the SLB Model. These have been developed from detailed event-tree type analysis and are considered to be a reasonably complete list of major initiating events which have been condensed from a larger list. Lester et al. (1981)
- 23 The reference facility site minimally meets all of the site suitability requirements set out in Chapter 5. The facility is also assumed to be operated in compliance with minimum radiation safety practices required by provisions of 10 CFR Part 20. Although the facility is assumed to comply with the NRC Branch Technical Position on Site Closure and Stabilization (Appendix II, no special effort is assumed regarding the waste form or design and operational practices to ensure long-term site stability. Several design and operational improvements directed at stability that have been instituted at some existing sites have not been assumed for the base case site (e.g., vibratory compaction of backfill material). This has been done to establish a base case level of long-term costs and radiological impacts against which measures to improve site performance, achieve greater site stability, minimize radiological impacts, and to ensure adequate funding can be assessed. The facility is described in detail in Appendix E. A brief description follows. USNRC (1981b)

A.10.1 Objectives and Taxonomy of Major Considerations

- 1 LLRHM goals for site selection are to: Falconer et al. (1981)
 (1) Protect present and future generations from unacceptable levels of radiation from waste radionuclides.
 (2) Allow access to required resources.
 (3) Minimize responsibilities and costs of WM to future generations.
- 2 The site shall be located in an area not subject to flooding. This criterion excludes floodplains, coastal areas prone to hurricanes or storm surges, and regulatory floodways. [Also] marshes, swamps, bogs, mudflats, and areas with small enough slopes that precipitation and snowmelt can pond. Falconer et al. (1981)
- 3 The site shall be located in areas where hydrogeologic conditions allow reliable performance prediction. Complex flow systems, such as in cavernous fractured materials, may not be suitable. Falconer et al. (1981)
- 4 The site shall be located where faults, liquefaction, landslides, volcanoes, or land subsidence will not jeopardize site performance. Falconer et al. (1981)
- 5 The site shall allow waste to be buried either completely above or below the transition between the unsaturated zones. For burial in the saturated zone, preferable earth materials are fine grained with low hydraulic conductivity such that molecular diffusion is the dominant solute migration mechanism. Falconer et al. (1981)
- 6 The site shall be selected with consideration given to current and projected population distributions. (Effects of accidental and chronic radiation releases, likelihood of human intrusion, etc.) Falconer et al. (1981)
- 7 The site shall be selected with consideration given to current and projected land use and resource development. It shall not be unique in its economic or esthetic value for industrial, agricultural, or recreational uses. It shall not prevent recovery of fuel, mineral, or water resources of present or potential economic value. Burial within an aquifer is unacceptable. Falconer et al. (1981)
- 8 To the extent consistent with other criteria, the site shall be selected with consideration given to location of waste generators, access to all-weather highway and rail-routes, and access to utilities. (to minimize transportation costs and risks) Falconer et al. (1981)
- 9 Site selection shall be consistent with federal, state, and local laws and regulations. Federal laws include: Clean Air Act, Clean Water Act, Safe Drinking Water Act, NEPA. Falconer et al. (1981)
- 10 The site shall not be within areas protected from such use by federal, state, or local laws and regulations. Falconer et al. (1981)

Federal laws include: Wilderness Act of 1964, Wild and Scenic Rivers Act of 1968, National Wildlife Refuge Act of 1966, National Parks National Historical Preservation Act of 1966, Archaeological and Historical Preservation Act of 1974, Heritage Conservation and Recreation Service.

11 Macbeth et al. (1979)

Important site selection factors are: site availability, distances to ground and surface meteorology and climatology, degree of remoteness, geologic stability, proximity to sources of waste and ownership for long-term control.

12 USHRC (1980b)

In selecting among alternative tailings disposal sites or judging the adequacy of existing sites, the extent to which a program meets the broad [NRC] objectives depends on:

- Remoteness from populated areas.
- Immobilization and isolation of contaminants from usable groundwater sources, [as provided by] hydrologic and other natural conditions.
- Potential to minimizing erosion, disturbance.
- Dispersion by natural forces over the long term.

13 Oztunali (1980)

The goals of LLW management and disposal are: (1) assurance of public health and safety; (2) protection of the environment and (3) minimization of the need for long-term social commitment. These goals can be achieved by assuring that: the potential population and occupational doses are within applicable limits and criteria, existing air and water quality standards are observed, direct and indirect impacts on public institutions and human environment are minimized, and the time periods for social commitment are controlled.

14 IAEA (1981)

A promising site for a waste repository can generally be initially selected through consideration of four fundamental factors, in sufficient detail to allow the decision to be made to commit resources for a detailed investigation of the site. These factors are: Hydrogeology, Ecology, Land Use/Status and Socio-economics.

15 IAEA (1981)

The factors relating to the social and economic aspects of shallow ground disposal are frequently difficult to measure or quantify, but they are important and can be decisive aspects of the site selection. The more important considerations include the following factors: (a) proximity to sources of waste, (b) adequacy of transport systems, (c) resources foregone by the commitment of land to waste disposal, (d) population density, (e) ownership and use of the land, (f) impact upon the community (e.g., employment) and (g) political constraints (including acceptance).

16 USHRC (1981a)

Primary emphasis in site suitability is on isolation of the waste, and on disposal site features that assure that the long-term performance objectives are met, as opposed to short term convenience or benefits.

17 Wilson (1978)

The significant issues are: dump sites should not be located in heavily populated areas; should not be located in or near land which is used for crops or pasture; dump sites should be covered by more than 30 feet of earth due to percolation which occurs because of freezing and thawing; local opinion must be solicited if a dump is proposed to be located in a given area; and local zoning laws should be adhered to.

A.10.2 Prescriptive Guidance

1 Falconer et al. (1981)

The site shall, (1) be of sufficient area and depth to accommodate the projected volume of waste and the buffer zone, and (2) include a 3-D buffer zone of sufficient size to allow unrestricted human use beyond its boundary-including withdrawal of water from aquifers.

2 USHRC (1981a)

The disposal site shall be capable of being characterized, modeled, analyzed, and monitored.

3 USHRC (1981a)

A disposal site should be selected so that projected population growth and future developments are not likely to affect the ability of the site to meet the performance objectives.

4 USHRC (1981a)

Areas must be avoided having economically significant natural resources whose exploitation would jeopardize meeting the performance objectives.

5 USHRC (1981a)

The site must be generally well-drained and free of areas of frequent ponding and flooding. [It must not be] in a 100 year flood plain-coastal high-hazard area or wetland.

6 USHRC (1981a)

Upstream drainage areas must be minimized.

7 USHRC (1981a)

[There must be] sufficient depth to the water table that groundwater intrusion, perennial or otherwise-into the waste will not occur. Exceptions will be considered if it can be shown conclusively that the predominant means of radionuclide movement is diffusion slow enough to meet the performance objectives.

8 USHRC (1981a)

Any groundwater discharge to the surface within the disposal site must not originate within the hydrogeologic unit used for disposal.

9 USHRC (1981a)

Areas must be avoided where tectonic processes such as faulting, folding, seismic activity, or volcanism may [jeopardize] the performance objectives or preclude defensible modeling and prediction of long-term impacts.

10 USHRC (1981a)

Areas must be avoided where surface geologic processes such as mass wasting, erosion, slumping, landsliding, or weathering [could] significantly affect [meeting] the performance objectives

or preclude defensible modeling and prediction of long-term impacts.

11 USHRC (1981a)

The site must not be located where nearby facilities or activities could adversely impact [meeting] the performance objectives or significantly mask the environmental monitoring program.

A.10.3 Preliminary Screening

- 1 Scoping identification of alternative remedial actions and candidate disposal sites will involve affected state and local authorities, EPA, MRC and other appropriate agencies. The principal issues to be examined will be identified, and responsibilities, schedule, and interfaces for conducting necessary studies will be agreed upon. USDOE (1980b)
- 2 The state is to identify candidate disposal sites for subsequent study during the [preliminary] engineering and environmental evaluation. DOE would support screening studies. USDOE (1980b)
- 3 Selection of the disposal site will take into consideration, as appropriate, preliminary MRC licensing evaluation of the site. USDOE (1980b)
- 4 Preliminary information from [MRC] indicates that licensing a site takes at least two years. Estimates for the time required for the siting process, including site development could range from three to five years. USDOE (1981a)
- 5 Preliminary site screening is to determine whether a state or region can site a facility at all. Finding a suitable site in an area is less likely if it contains one or more of the following: wetlands, shallow ground-water tables, high precipitation and low runoff, flood plains, large population, or valuable lands. USDOE (1981a)
- 6 Screening based on field reconnaissance will investigate geology and topography, hydrology and meteorology, seismology and volcanology, socioeconomics and land use, ecology, soil types. USDOE (1981a)
- 7 Determination of the potential hazards from long-lived radionuclides [is a priority technical issue]. Deichman (1979)
- 8 A proposed disposal site [would be] selected on the basis of reconnaissance level information. USMRC (1981a)

A.11 OTHER LAND DISPOSAL OPTIONS

- 1 BY 1981, DOE and NRC should review existing and alternative LLW disposal techniques and determine whether any should be adopted in the near future. USDOE (1979)
- 2 LLW disposal alternatives considered by Macbeth et al. (1978) but not selected for further evaluations are: extraterrestrial, atmospheric, mixing into soil and leaching ponds, release to aquifers, hydrofractured geologic strata, seabed, ice sheets, submantle, conversion. Which, if any, need to be considered beyond cursory listing to demonstrate completeness? Macbeth et al. (1978)
- 3 Results of preliminary engineering evaluation, environmental analysis, and DOE conclusions as to preferred waste disposal option and reasonable alternatives will be communicated, for review and comment, by DOE to appropriate federal, state and local agencies and to the public. USDOE (1980b)
- 4 All major alternative disposal methods were identified in an NRC/FBDU study (Macbeth 1978), without elaboration in detail of minor variations and combinations of approaches or of site-specific considerations. Macbeth et al. (1979)
- 5 Alternatives selected for detailed evaluation are: SLB, improved SLB, deeper burial (IDB), disposal in mine cavities, disposal in engineered structures, disposal in the ocean. Macbeth et al. (1979)
- 6 For comparisons of alternatives, no costs common to all disposal alternatives and borne by waste generators are included in Macbeth's cost estimates, which therefore do not represent actual cost. Macbeth et al. (1979)
- 7 Analysis of radionuclide movement for the purpose of comparing alternative sites should take into account climatic, edaphic, geologic, and hydrologic conditions. Deichman (1980)
- 8 For the purpose of this chapter, a geologic repository as defined in Part 60 is not considered a land disposal facility. USNRC (1981a)
- 9 Disposal site suitability requirements for land disposal other than near-surface [are for future rulemaking]. USNRC (1981a)
- 10 Disposal site design [requirements] for other than near-surface disposal [are reserved for future rulemaking]. USNRC (1981a)
- 11 Facility operations and disposal site closure [requirements] for land disposal facilities other than near-surface [are reserved for future rulemaking]. USNRC (1981a)

- 12 NRC may, upon request or on its own initiative, authorize provisions other than those set forth in sections 61.51 through 61.53 for the segregation and disposal of waste and for the design and operation of a land disposal facility on a specific basis, if it finds reasonable assurance of compliance with the performance objectives of Subpart C of this part. USNRC (1981a)
- 13 Perhaps the only viable site release option for existing sites that contain significant inventories of long-lived radioisotopes is conditional release with land use restrictions and administrative control of the site. Murphy and Holter (1980)
- 14 The naturally occurring uranium series radioactivity appearing in phosphate mining spoils and the waste and by products of beneficiation and chemical plant operations is for the most part contained in large volumes of relatively low radioactivity concentrations. The solution to management of materials and lands with radioactivity levels that do not meet unrestricted use criteria consists of (1) restricting land and materials use and/or (2) selective in situ placement of higher radioactivity materials in a manner that meets criteria for the desired use. Roessler et al. (1979)
- 15 In view of the large quantities of relatively low activity materials and considerations such as the need for overburden and tailings as replacement for mined volumes, the potentially recoverable phosphate and uranium resources of dewatered clays, and the superiority of furnace slag to other materials locally available as aggregates, it is neither practical nor prudent to ship these materials to off-site burial grounds as is done with small quantities of "conventional" low level radioactive waste from the nuclear industry and nuclear research. Roessler et al. (1979)

A.11.1 Stabilization and Engineered Structures

- 1 Interim storage onsite or offsite should be allowed while disposal capacity is being developed. Levin (1980)
- 2 Is disposal in manmade structures an acceptable and cost-effective alternative for some FUSRAP waste? Macbeth et al. (1978)
- 3 The major question regarding disposal in manmade structures is its ability to confine the waste under all conditions for the time periods required. Macbeth et al. (1978)
- 4 Interim storage would increase both occupational exposure and population risk. USDOE (1981b)
- 5 Can the methodology used to analyze the cost-benefit consequences of changing the defining interface between nonradioactive waste and low-level radioactive waste be used to help resolve the issue of whether FUSRAP waste at a particular site could be stabilized in place rather than moved to a near-surface disposal facility? Adam and Rogers (1978)

- 6 Macbeth et al. (1979)
Enclosing the radioactive waste in engineered structures may offer advantages over SLB. Some of these advantages have been exploited in certain structures used to store wastes in Canada.
- 7 Macbeth et al. (1979)
A structural disposal facility (SDF) would be built of reinforced concrete, for greatest durability and fire resistance at reasonable cost. Both exposed and covered structures could be built, at any appropriate location.
- 8 Macbeth et al. (1979)
Accident dose rates might be reduced from those for current SLB practice by a factor of two for SDF disposal, since at least half the waste handling occurs inside the containment provided by the structure.
- 9 Murphy and Holter (1980)
Waste relocation involves the exhumation of buried waste, repackaging of the waste if necessary, and reburial of the waste at another disposal site or in another trench on the same site. Exhumation of waste originally buried without any intent of later retrieval is an expensive and time-consuming operation that has a potential for significant radiation exposure to decommissioning workers. Therefore, waste relocation would likely be considered only in situations where other decommissioning procedures are inadequate to ensure that future risk from the facility is within acceptable bounds.
- 10 Murphy and Holter (1980)
Estimated time required to relocate the waste from an entire reference burial ground range from 20 to 25 years.
- 11 Murphy and Holter (1980)
Inhalation doses to decommissioning workers are expected to be negligible for site stabilization and long-term care, since these operations do not normally involve direct contact with buried waste or contaminated soil. However, waste relocation operations may involve the generation of dust containing radioactive particulates, and these operations could result in substantial inhalation doses. The use of respiratory equipment to minimize inhalation doses from those operations which have potential for the generation of airborne radioactivity, is assumed.
- 12 Murphy and Holter (1980)
As shown in Table 13.4-2, the option of relocating an entire trench offsite could result in two to three nonradiological injuries. For no cases would a fatal injury be expected, and for the other options even the probability of nonfatal injury is slight. However, relocating 100,000 to 200,000 cubic meters offsite (truck transport assumed), about 12 to 24 reference site trenches, would carry an expectation of from one to three fatalities.
- 13 Murphy and Holter (1980)
Perhaps the only viable site release option for existing sites that contain significant inventories of long-lived radioisotopes is conditional release with land use restrictions and administrative control of the site.

A.11.2 Deeper Burial

- 1 Comp. Gen. of U. S. (1980)
IDB not yet a proven disposal technique. Is it a viable option for FUSRAP?
- 2 Macbeth et al. (1978)
What experience has there been, either in the U.S. or elsewhere, in utilizing old strip mines for LLW disposal?
- 3 Deichman (1979)
Evaluation of the technical feasibility of Intermediate Depth Burial (IDB) is a priority technical issue. In comparison to SLB, for example, there is increased isolation of waste, greater operational costs, decreased distance to water table.
- 4 USDOE (1981b)
Disposal costs (exclusive of transportation) are not overly sensitive to the higher costs for deeper burial or even mined cavity disposal of part of the LLW so long as that part is only, say, 10% of the total waste.
- 5 Macbeth et al. (1979)
Sites for intermediate depth burial (IDB) are less plentiful than for SLB, but many areas of the country have more than adequate soil depth.
- 6 Macbeth et al. (1979)
IDB would provide significantly greater isolation and protection against inadvertent intrusion than SLB. For example, most reclamation activities would not involve excavation to the depth of the waste.
- 7 Macbeth et al. (1979)
The incremental costs for IDB as compared to those of SLB are about 10% of the total disposal costs, and the incremental waste management costs (i.e., economic impact) are also about 10% of the total.
- 8 USNRC (1980b)
The "prime option" for tailings disposal is placement below grade either in mines or specially excavated sites (that is, where there is no need for any specially constructed retention structure).
- 9 Kuck and Hacks (1980)
The most viable near-term alternative to shallow land burial appears to be space mined specifically for LLW disposal.
- 10 Deichman (1980)
Intermediate-depth burial (IDB) would position the waste farther from plant root systems and fauna than does shallow land burial (SLB) and reduce the potential for exposure by erosion and intrusion by humans. These advantages should be weighed against the increased cost, reduced distance between waste and the water table, and the alternative of placing more effective barriers in trench covers of conventional SLB trenches.
- 11 Murphy and Holter (1980)
Deep geological disposal charges assumed in this and other studies are about one order of magnitude higher than for SLB.
- 12 Murphy and Holter (1980)
Engineered storage could be provided for wastes likely to require relocation at some future time.
- 13 USNRC (1981b)
Both the design and operation of the example intermediate depth disposal facility differ significantly from the reference disposal facility described in Appendix E. The

excavation is assumed to be a circular open-pit with a spiral access road leading down into the excavation. The excavation is roughly circular with a 410 m diameter at the base of the excavation and a 480 m diameter at ground surface. The maximum depth of the excavation is 34 m. The disposal cell consists of three layers of waste each 5 m thick. Each layer of waste is replaced by forklifts and boom cranes within the excavation. Random emplacement is assumed throughout the operations with a void space utilization of 50% assumed. For purposes of analyses, an average annual waste input of 50,000 m³ (1.77 million ft³) over 20 years duration is assumed.

14 USHRC (1981b)

Commentors who offered an opinion on Intermediate Land Burial as an LLW method were divided. The comment offered most frequently was that the bulk of the waste would be contained longer, but the increased cost would not be justified by the relatively insignificant hazard.

A.11.3 Dispersal

1 Compt. Gen. of U. S. (1980)

Adequate definition of LLW is lacking, and needed for optimal screening of disposal options (e.g. SLB, Intermediate Depth Land Burial (IDLB), landfill).

2 Macbeth et al. (1978)

Could dilution of some FUSRAP waste be accomplished acceptably and bring activity concentrations to levels at which disposal would be allowable in sanitary land fills, in strip mines or abandoned quarries, or by ocean dumping less constrained as to packaging?

3 USDOE (1981b)

The issue of environmental releases deserves a high priority. Central is the lack of consistency between current requirements for disposal of LLW in solid form and regulations allowing certain concentrations of liquid and gaseous radioactive materials to be released to the environment.

4 USDOE (1981b)

The principle of dilution and dispersion has long been an accepted treatment for certain pollutants, and is the basis of current practice [when] releases of radioactive liquids and gases [is allowed].

5 USDOE (1981b)

Current practice does not allow the release of solid radioactive waste into the environment. Items with surface activity can be decontaminated and recycled, but items with internal contamination from neutron activation must be shipped to disposal sites whatever their potential of hazard.

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