Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground

Environmental Surveillance Programs


Pacific Northwest Laboratory
Operated by
Battelle Memorial Institute

Prepared for
U.S. Nuclear Regulatory Commission
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Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground

Environmental Surveillance Programs

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FOREWORD

BY

NUCLEAR REGULATORY COMMISSION STAFF

The NRC staff is reappraising its regulatory position relative to the decommissioning of nuclear facilities. (1) As a part of this activity, the NRC has initiated series of studies through technical assistance contracts. These contracts are being undertaken to develop information to support the preparation of new standards covering decommissioning.

The basic series of studies will cover the technology, safety, and costs of decommissioning reference nuclear facilities. Light water reactors and fuel cycle and non-fuel-cycle facilities are included. Facilities of current design on typical sites are selected for the studies. Separate reports will be prepared as the studies of the various facilities are completed.

The first report in this series was published in FY 1977 and covered a fuel reprocessing plant; (2) the second was published in FY 1978 and covered a pressurized water reactor; (3) the third of the series was published in FY 1979 and dealt with a small mixed oxide fuel fabrication plant. (4) An addendum to the pressurized water reactor report, (5) which examined the relationship between reactor size and decommissioning cost, the cost of entombment, and the sensitivity of cost to radiation levels, contractual arrangements, and disposal site charges, was issued during FY 1979. The fifth report in this series dealt with a low-level waste burial ground. (6) The sixth report dealt with a large boiling water reactor power station. (7) The seventh report provided information on the technology, safety, and costs of decommissioning a uranium fuel fabrication plant. (8) The eighth report in the series covers the decommissioning of non-fuel-cycle nuclear facilities.
Additional topics will be reported on the tentative schedule as follows:

- FY 1981 o Multiple Reactor Facilities
- FY 1981 o Research/Test Reactors
- FY 1981 o UF₆ Conversion Plant
- FY 1982 o Independent Spent Fuel Storage Installations
- FY 1982 o Light Water Reactor Accidents

The second series of studies covers supporting information on the decommissioning of nuclear facilities. Four reports have been issued in the second series. The first consists of an annotated bibliography on the decommissioning of nuclear facilities. (10) The second is a review and analysis of current decommissioning regulations. (11) The third covers the facilitation of the decommissioning of light water reactors, (12) identifying modifications or design changes to facilities, equipment, and procedures that will improve safety and/or reduce costs, and the fourth in the series covers establishment of an information base concerning monitoring for compliance with decommissioning survey criteria. (13) A fifth report on this same theme is intended for FY 1981 (14).

The following report is an addendum to the low-level waste burial ground report which supplements and, to some extent, replaces the preliminary description of environmental radiological surveillance programs for low-level waste grounds used in the parent document. In the parent document such preliminary description was done primarily for cost estimating purposes.

The information provided in this report on decommissioning survey on compliance monitoring, including any comments, will be included in the record for consideration by the Commission in establishing criteria and new standards for decommissioning. Comments on this report should be mailed to:

Chief
Chemical Engineering Branch
Division of Engineering Technology
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

for technical implementation.
REFERENCES


This Addendum supplements, and to some extent replaces, the preliminary description of environmental radiological surveillance programs for low-level waste burial grounds (LLWBG) used in the parent document, "Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground," NUREG/CR-0570. The Addendum provides additional detail and rationale for the environmental radiological surveillance programs for the two referenced sites and inventories described in NUREG/CR-0570. The rationale and performance criteria herein are expected to be useful in providing guidance for determining the acceptability of environmental surveillance programs for other inventories and other LLWBG sites.

Two generic burial grounds, one located on an arid western site and the other located on a humid eastern site, are reference facilities considered in this Addendum, and as described in the parent document (NUREG/CR-0570). The two sites are assumed to have the same capacity for waste, the same radioactive waste inventory, and similar trench characteristics and operating procedures. The climate, geology, and hydrology of the two reference sites are typical of existing western and eastern sites, although a single population distribution was chosen for both. Each reference burial ground occupies about 70 hectares and includes 180 trenches filled with a total of $1.5 \times 10^6$ m$^3$ of radioactive waste. In addition, there are 10 slit trenches containing about $1.5 \times 10^3$ m$^3$ of high beta-gamma activity waste.

In this Addendum environmental surveillance programs are described for the several periods in the life of a LLWBG: preoperational (prior to nuclear waste receipt); operational (including interim trench closures); post-operational (after all nuclear waste is received), for both short-term (up to three years) and long-term (up to 100 years) storage and custodial care; and decommissioning (only for the special case of waste removal). The specific environmental monitoring requirements for final site characterization and certification surveys are beyond the scope of this Addendum.
Data collection associated with site reconnaissance and preselection is not specifically addressed, but it is recognized that such data may be useful in designing the preoperational program. Predisposal control measures, quality assurance, and record-keeping (other than inventory records) associated with waste disposal operations are also not addressed.

The primary intent of routine environmental surveillance at a LLWBG is to help ensure that site activities do not cause significant transport of radioactivity from the site, resulting in an unacceptable health hazard to people. Preoperational environmental surveillance serves to determine for later comparison the background radioactivity levels, either naturally occurring or the result of man's activities (e.g. world-wide fallout or an adjacent nuclear facility), in and around the proposed burial ground site. The operational environmental surveillance program is used to estimate radiological conditions, both onsite and offsite as a possible result of burial ground activities, including trench closure(s). These data help to determine LLWBG compliance with regulatory requirements. During the post-operational period environmental surveillance should normally be an extension of the program carried out during operations, with appropriate deletions (or modifications) to account for the differences between operational and post-operational activities at the site.

During the long-term storage and custodial care period, environmental surveillance serves to verify the radionuclide confinement capability of the burial ground and to identify problem situations requiring remedial action. For waste removal (exhumation), the environmental surveillance program is again modified to account for the greatly increased potential for direct radiation and contamination spread. At the time of decommissioning, "environmental surveillance" takes on a new meaning, from that of an ongoing program to one of site "characterization" and dose assessment, requiring more rigorous statistical design and testing than described for the other surveillance periods at a LLWBG.

The environmental surveillance programs suggested in this Addendum are based on the radionuclide inventories given in Section 7 of NUREG/CR-0570 and
the potential critical pathways determined for the reference sites. The Addendum suggests the use of exposure pathway analysis to evaluate the potential critical pathways to man from radionuclides in the waste. Hence, the monitoring programs recommended for the two reference sites include those nuclide/media resulting in the highest potential radiation dose or those in which the greatest buildup of contaminants can be expected. Appropriate use is made of existing regulations and other published reports and guides on the subject of environmental surveillance.
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ENVIRONMENTAL SURVEILLANCE PROGRAMS FOR LOW-LEVEL WASTE BURIAL GROUNDS:
ADDENDUM TO NUREG/CR-0570

1.0 INTRODUCTION

The environmental surveillance programs for each period in the life of a low-level waste burial ground (LLWBG) are directly related to the program at preceding and following stages. Therefore it is appropriate to discuss in a single document the contents of the program at all stages from preoperational to post-operational, including long-term storage and custodial care as well as their relationship to decommissioning.

1.1 BACKGROUND

Over the past several years, the Office of Standards Development (OSD) of the Nuclear Regulatory Commission has sponsored a series of studies of the technology, safety and costs of decommissioning various nuclear facilities.\(^1\)\(^-\)\(^7\) One of those studies, NUREG/CR-0570,\(^4\) addresses commercial low-level waste burial grounds (LLWBG). It includes some discussion of radiological surveillance of the reference environments both during and after decommissioning, but in only enough detail for costing and assurance of adequate technical feasibility. More recently a draft impact statement was issued on the decommissioning of nuclear facilities,\(^8\) but it too did not include surveillance program details on LLWBGs. Therefore this Addendum to NUREG/CR-0570 is provided to develop technical bases for formulating and implementing environmental surveillance programs at the reference LLWBG sites.

1.2 OBJECTIVES AND SCOPE

This Addendum is intended to describe an acceptable program of environmental radiological surveillance by a licensee for the low-level waste burial ground and waste inventory at each of the two reference sites described in NUREG/CR-0570. The rationale and performance criteria provided herein are
expected to be useful in providing guidance for determining the acceptability of environmental surveillance programs for other inventories and other LLWBG sites.

A program is described for each of the following periods in the life of the reference LLWBG sites: preoperational; operational (including interim trench closures); post-operational, both short (up to three years) and long-term (up to 100 years); and for the special decommissioning case of waste exhumation (e.g., high beta-gamma activity waste or those containing high concentrations of transuranics--TRU). Data collection associated with site reconnaissance and preselection is not specifically addressed, but may be useful in designing the preoperational program. Quality assurance operations, predisposal control measures, quality assurance, and record-keeping associated with waste disposal operations are also not addressed.

1.3 DEFINITIONS

Section 16 of NUREG/CR-0570(4) included a Glossary of definitions as did Appendix C, Volume 2. Selected definitions from those lists have been modified and are reported here.

Aquifer: a subsurface formation containing sufficient saturated permeable material to yield significant quantities of water.

Background: that level of radioactivity from sources existing without the presence of a LLWBG, including nonsite-related sources, such as might result from atmospheric weapons testing or from another nuclear facility operating in the vicinity.

Bentonite: means a porous clay, produced by the natural decomposition of volcanic ash, that is able to absorb much water and swell greatly as a result.

Buffer Zone: means the real property controlled by the licensee (LLWBG operator), which is not used for waste disposal purposes, but which completely encompasses the area used by the licensee for waste disposal.
Byproduct Material means byproduct material as defined in the regulations contained in 10 CFR 30. Byproduct materials include principally activation and fission products (e.g. $^{60}\text{Co}$, $^{90}\text{Sr}$, $^{137}\text{Cs}$).

Code of Federal Regulations (CFR) means the documentation of the general rules by the Executive departments and agencies of the Federal Government. The Code is divided into 50 "Titles" of broad areas subject to Federal regulation. Each Title is further divided into Chapters which are further subdivided into "Parts" (e.g. 10CFR30 means Title 10, Part 30).

Contamination means undesired radioactive materials that have been deposited on the surfaces of, or are internally ingrained into, structures or equipment, or that have been mixed with another material.

Critical Path is the radionuclide-organ-pathway resulting in the largest percentage of the applicable dose criterion, even though the projected dose may be extremely small (see also, Exposure Pathways).

Custodial Safe Storage means a minimum cleanup and decontamination effort is made of the LLWBG initially, followed by a period of interim care with the active protection systems (i.e., ventilation, utilities, fire) kept in service. The site is secured by physical barriers and by guards against intrusion. Use of the site is limited to nuclear activities.

Decommissioned means a LLWBG site that has been released for unrestricted use, following site certification and termination of the license. (A site that is decommissioned has been certified, is no longer licensed, and no longer requires environmental surveillance or maintenance.)

Decommissioning of a LLWBG means the final activities carried out at the site after completion of active waste receipt and disposal operations, and an interim storage period (as deemed necessary) to prepare the site for unrestricted release. This may involve such activities as: waste exhumation (TRU), dismantling site structures, decontaminating site surfaces, and conducting final site radiological characterization and certification.

Decontamination means those activities employed to reduce the levels of contamination in or on structures, equipment, and materials.
Dismantlement includes those actions required to disassemble and remove sufficient radioactive or contaminated materials from the LLWBG site, to permit release of the property for unrestricted use.

Distribution Coefficient \( (K_d) \) is a measure of the volume of water "retained" or "retarded" by a unit mass of soil, expressed in \( l/kg \). In this study, it is taken as the proportionality constant between the concentration of the sorbed contaminant on the solid phase (the porous medium) and the concentration in the fluid (water) at equilibrium.

Effective Porosity is the property of rock or soil containing intercommunicating interstices expressed as a percent of bulk volume occupied by such interstices.

Engineered Barriers are man-made devices to contain or limit the movement of waste material (radionuclides) from LLWBG. Engineered barriers may include, for example, waste forms, waste packages, means to restrict the contact of water with the waste material, or means to retard the movement of the waste by water.

Environmental Surveillance (or Monitoring) is a program to monitor the impact of LLWBG operations on the surrounding region and to monitor the extent and consequences of potential migration of radioactivity from the burial ground site. A specific program stipulates the types of samples, points at which samples are taken, the frequency of sampling and types of analyses conducted on samples to verify the effectiveness of a site and operations to safely contain the waste disposed of at the site. It includes preoperational, operational, and post-operational phases. (In this document, the term "surveillance" is used as equivalent to the term "monitoring.")

Exhumation is the process of removing buried waste from the earth at a LLWBG by digging.

Exposure Pathways are potential routes by which people may be exposed to radionuclides or radiation. In this study, inhalation of radioactive particulates, external exposure from the waste, and ingestion of food products, drinking water, and/or animals containing radionuclides of possible LLWBG origin are considered.
Food Chain means the pathways by which any material in the environment (such as radioactive material from fallout) passes through edible plants and/or animals to man.

Glaciofluvial Deposit includes sediment deposited from a river fed by a glacier.

Ground Water is water that exists or flows below the ground surface (within the zone of saturation).

Hydraulic Conductivity is a measure of the capacity of a rock to transmit fluid.

Hydraulic Gradient is the slope of a water table, found by determining the difference in height between two points and dividing by the horizontal distance between them.

Hydrology is the science dealing with the waters of the earth, their distribution on the surface and underground, and the cycle involving precipitation, flow to the seas, evaporation, evapotranspiration, etc.

Institutional Controls are activities or devices which involve the performance of functions by human beings to limit contact between the waste at a LLWBG and humans.

Interim Storage includes operations for which a) monitoring and human control are provided and b) subsequent action (e.g., decommissioning) is expected.

Leaching is the process of removal or separation of soluble components from the wastes buried at a LLWBG by contact with water or other liquids. (This process is considered to represent one of the significant routes of LLWBG radioactivity to ground water.)

License means a license issued under the regulations in Chapter I of Title 10 of the Code of Federal Regulations. (9-15) Licensee (site operator) means the holder of such license.

Loess is wind-deposited silt, usually accompanied by some clay and some fine sand.
**Long-Term Care** refers to the period following termination of burial operations during which institutional control of the site is maintained. Activities performed during this period include environmental monitoring and routine surveillance and maintenance of the site. Decommissioning may follow the long-term care period.

**Low-Activity Bulk Solids** means any source, byproduct, or special nuclear material waste that is characteristically 1) homogeneously dispersed in small concentrations throughout large volumes of inert material, and 2) difficult to appreciably concentrate or reduce in volume. Such waste includes slags or tailings from nuclear fuel fabrication plants, but does not include uranium mill tailings or combustible material such as papers or rags.

**Low-Level Waste** (LLW) or **Low-Level Radioactive Waste** means any source, byproduct, or special nuclear material that meets appropriate waste acceptance criteria defined in specific Titles, Parts and Subparts of the CFR.

LLW does not include:

a. high-level waste, as defined in Appendix F of 10CFR50;¹(13)
b. irradiated nuclear reactor fuel;
c. uranium mill tailings, as defined in 10CFR40;⁽¹²⁾
d. waste material containing or contaminated with radionuclides in concentrations exceeding the concentrations allowed by the NRC in waste to be disposed of as LLW;
e. radioactivity in effluents released to unrestricted areas and to sanitary sewer systems as defined in Sections 20.106 and 20.303 of 10CFR20;⁽¹¹⁾
f. low-activity bulk solid waste.

**Maximum-Exposed Individual** is a hypothetical member of the public who receives the maximum radiation dose to an organ of reference. The maximum-exposed individual is assumed to reside at the location (on or offsite) where the highest radiation exposure is predicted for the specific inventory at a LLWBG. Maximized exposure pathway parameters are used.
Natural Barriers include the natural characteristics of a LLWBG site or surface and subsurface composition that serves to impede the movement of waste material. Natural barriers may include, for example, the location of the waste remote from an aquifer, or the sorptive capability of the soil surrounding the waste.

Perched Water is subsurface water existing or trapped in a restricted aquifer above the active water table.

Permeability is the measure or the capacity of a medium (rock or soil) for transmitting a fluid (water) under a hydro-potential gradient.

Porosity is the ratio of the aggregate volume of interstices in a rock soil to its total volume.

Post-Operational activities include the maintenance and environmental monitoring conducted at a LLWBG site after termination of waste receipt, but prior to transfer to a custodial agency to ensure that the facility continues to safely contain the emplaced wastes.

Release Agent is the first in any series of radionuclide transport mechanisms, acting at the point of radionuclide release from a burial trench, initiating the release.

Restricted Area includes any area to which access is controlled for protection of individuals from exposure to radiation and radioactive materials.

Saturated Zone is the subsurface zone in which all of the interconnecting interstices (void spaces or pores) are filled with water.

Segregation of Waste means the actions taken by the licensee (site operator) to 1) identify the characteristics of the as-received LLW, including the waste type, form, chemical content, and radionuclide content and concentration, and 2) direct the LLW to separate disposal methods or separate storage and disposal locations on the LLWBG site as may be required to assure safety and compliance with federal regulations.

Silt refers to sediment particles having diameters larger than 4 microns and smaller than 0.0625 mm (about the lower limit of visibility of individual particles with the unaided eye).
Site means the real property, including the buffer zone, on which a LLWBG may be located. A site used for a LLWBG includes a boundary and a buffer zone, and the property controlled by the licensee.

Site Certification is the documentation that confirms that residual contamination levels at the LLWBG site are not above the pre-established design objective limits. Site certification precedes license termination and unrestricted release of the site.

Site Operations means the routine day-to-day activities carried out by the site operator (licensee) for the receipt, storage, treatment, and disposal of waste.

Site/Waste Stabilization means the use of engineered procedures to reduce the mobility of buried waste and to protect the waste from the effects of potential release agents.

Solid Radioactive Waste includes material that is essentially solid and dry, but may contain sorbed radioactive fluids in sufficiently small amounts as to be immobile.

Source Material means thorium, natural or depleted uranium, or any combination therefore as defined in 10CFR40. (12)

Special Nuclear Material includes plutonium, $^{233}$U, uranium containing more than the natural abundance of the isotope 235 or any material artificially enriched with the foregoing substances as defined in 10CFR70. (15)

Subsidence is a sinking or collapse of the trench cap or ground surface, which may expose buried waste materials or contaminated soil.

Terminate a License means action by the NRC to relieve the licensee of any further legal responsibility for the site.

Till means nonsorted glacial drift.

Transuranic Waste (TRU) includes any waste material measured or assumed to contain more than a specified concentration (i.e., proposed as 10 nanocuries of alpha emitters per gram of waste, or more recently as 100 nanocuries of $^{239}$Pu per cm$^3$ of waste) of transuranic elements (elements with atomic number, Z, greater than 92).
Vadose Zone is the unsaturated region of soil between the ground surface and the water table.

Waste Relocation is the exhumation of buried waste, repackaging of the waste if necessary, and reburial of the waste at another repository or in another trench on the same site.

Water Table means the upper boundary of an unconfined aquifer below which saturated ground water occurs. It is defined by the level at which water stands in wells that barely penetrate the aquifer.

1.4 REFERENCES


*Available for purchase from the NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, DC 20555 and/or the National Technical Information Service, Springfield, VA 22161.

**Single copies are available free upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.
2.0 BASES FOR ENVIRONMENTAL SURVEILLANCE AT LOW-LEVEL WASTE BURIAL GROUNDS

Low-level waste burial grounds (LLWBG) are provided to isolate certain\(^{(a)}\) radioactively contaminated waste materials from man's immediate environment. This Section provides a listing of the objectives, applicable regulations (standards and guides), and potential exposure pathways to be considered in designing environmental surveillance programs. These monitoring programs should provide reasonable assurance that each site continues to provide the waste isolation desired.

2.1 ENVIRONMENTAL SURVEILLANCE OBJECTIVES

Environmental surveillance programs are designed and implemented to assure that site activities do not cause significant transport of radioactivity from the site, either as a result of site activities or its mere existence, resulting in an unacceptable health hazard to the public. Many statements of environmental surveillance objectives have been made,\(^{(1-6)}\) although none are specific to LLWBGs. Environmental surveillance programs for LLWBGs should provide reasonable assurance that sufficient sampling locations are provided and that sampling and analyses are provided in sufficient frequency to:

- Detect changes and evaluate long-term trends of radioactivity in the environment, with the intent of including all significant pathways and modes of exposure to contaminants (either known or made known through the program), of quantifying the movement of contaminants, and of initiating appropriate remedial actions, if necessary.

- Assess the actual or potential exposure of man and local ecosystems from radioactive materials buried at or transported to the environment from the LLWBG.

- Demonstrate compliance with applicable license conditions concerning the impacts of contaminants on the environment and the maintenance of adequate records.

\(^{(a)}\) See definition of low-level wastes in Section 1.3.
Maintain a data base and records system to support all of the above.

A primary objective of environmental surveillance at LLWBGs is to evaluate environmental impacts from waste disposal operations and the attendant follow-up activities of site/waste stabilization, long-term care, and waste exhumation (if required). Preoperational programs for LLWBG sites should therefore include both direct radiation measurements and radioanalyses of environmental media for which a causal relationship between LLWBG operations and adverse change has been established (from other LLWBG experience) or may be strongly suspected. Media and analyses suggested for all phases of environmental surveillance at the reference LLWBGs are provided in Sections 4 to 7 of this Addendum.

Preoperational environmental surveillance serves to determine the normal, or "background," radionuclide concentrations in and around the proposed burial ground site. The operational environmental surveillance program provides data on the radiological conditions both onsite and offsite, which aids in determining compliance with regulations. Following the preoperational period, each subsequent phase of a monitoring program must be tailored to that LLWBG and its operating experiences, and should retain sufficient flexibility to allow modification if the need arises. Further, periodic evaluation of the findings of the surveillance programs will provide the basis for modification to ensure that the surveillance effort is sufficient and justified when compared to current assessment of the effect that the respective LLWBG site is having on the environment.

Post-operational environmental monitoring programs should normally be extensions of the program carried out during burial ground operations, with appropriate additions or deletions to account for differences between operational and post-operational activities at the site. During this period, environmental surveillance serves to verify the radionuclide confinement capability of the burial ground and to identify problem situations requiring remedial action. During the decommissioning phase, environmental surveillance either serves to monitor waste exhumation activities or to provide a statistically based program to prepare for site certification. The latter is not addressed here as it is not within the scope of this Addendum.
These general objectives of environmental surveillance at low-level waste burial grounds are summarized in Table 2.1-1. They are based to some degree on existing programs at the six commercial LLWBG sites in the U.S., on NRC Regulatory Guides, and on published environmental surveillance Guides.

2.2 STANDARDS AND CRITERIA

The continuing enactment of environmentally-oriented legislation at Federal, state, and local levels makes any discussion of regulatory requirements and authorities subject to continuing amendment. The following therefore reflects the status of regulations and federal guidelines only as of the end of 1980, but can be used as a departure point for future reference.

2.2.1 Radiological Guidance

If not properly controlled, various nuclear activities could have an unacceptable impact on both worker and public health and safety, as well as on environmental quality. Included in such activities are the decommissioning of nuclear facilities, as well as the processing, storage, transport and disposal of the resulting radioactive and non-radioactive wastes. Limiting the acceptable impacts from nuclear operations are a number of existing performance standards, embodied either in the Code of Federal Regulations or comparable codes of state governments.

Although an extensive framework of governmental requirements may apply to LLWBGs, many of these requirements do so only indirectly. It is expected, however, that the regulatory framework of requirements will become more explicit with regard to nuclear wastes and to decommissioning of nuclear facilities, in itself a major future source of low-level wastes.

Increased regulatory attention to decommissioning issues, by the Nuclear Regulatory Commission and other governmental agencies as well, will result eventually in the establishment of a comprehensive and systematic body of requirements governing these activities.
<table>
<thead>
<tr>
<th>Preoperational Phase</th>
<th>Operational Phase</th>
<th>Post-Operational Phase</th>
<th>Decommissioning Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Determine natural and man-made radioactivity patterns</td>
<td>• Determine onsite and offsite radiological conditions above background</td>
<td>• Assess actual or potential exposure to man from site operations</td>
<td>• Determine impact of decommissioning activities on local environment</td>
</tr>
<tr>
<td>• Estimate background radiation levels and radionuclide concentrations</td>
<td>• Assess actual or potential exposure to man from site operations</td>
<td>• Demonstrate compliance with applicable regulations</td>
<td>• Evaluate whether decommissioning operations are in compliance with regulations</td>
</tr>
<tr>
<td>• Investigate critical pathways to man</td>
<td>• Determine relationships between in situ measurements and environmental concentrations</td>
<td>• Maintain data base and records system</td>
<td>• Assure continued radioactive waste confinement</td>
</tr>
<tr>
<td>• Determine relationships between in situ measurements and environmental concentrations</td>
<td>• Evaluate sampling and analytical methods</td>
<td>• Ensure continued radioactive waste confinement</td>
<td>• Compare environmental conditions with potentially changing regulations</td>
</tr>
<tr>
<td>• Evaluate sampling and analytical methods</td>
<td>• Arrange sampling agreements with nearby residents/businesses</td>
<td>• Post-Operational Phase</td>
<td></td>
</tr>
</tbody>
</table>
No attempt has been made here to discuss the variety of potentially applicable design and engineering standards, such as local building codes, architectural standards, and equipment manufacturers' design standards. Also omitted are many voluntary consensus standards, including those issued under the auspices of the American National Standards Institute. Any of these may of course become mandatory on a case-by-case basis if incorporated by reference in construction permits, purchase requisitions, or operating licenses.

Table 2.2-1 lists applicable regulations and other guidance possibly pertinent to low-level waste burial grounds. The specific items listed are grouped according to source (Code of Federal Regulations, NUREG documents and Regulatory Guides issued by the NRC, and other environmental regulations). The regulations listed in Part A specifically apply to LLWGBs, at least to some degree. Those in Part B are of either an advisory nature only or specifically apply to other nuclear operations and facilities.

2.2.2 Other Environmental Regulations

It is beyond the scope of this Addendum to address the non-radiological permitting, monitoring, and reporting requirements that could be imposed on LLWBG operators by the many environmental regulations outside the purview of NRC. However, several environmental acts and corresponding regulations, enforced by the Environmental Protection Agency or by the States, may interact with NRC's regulations for LLWGBs.

It is the intent of the Clean Water Act (CWA)\(^{(45)}\) to protect surface waters of the United States. The act regulates point source discharges of pollutants into "navigable bodies of water." Navigable bodies of water include virtually all surface waters in the United States according to the definition of the Corp of Engineers. An approved LLWBG site would not be expected to discharge water to any stream, either as surface runoff or percolation through the soil, and hence should not be regulated under the Clean Water Act.
<table>
<thead>
<tr>
<th>Identification</th>
<th>Description</th>
<th>Reference Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 CFR 20</td>
<td>Radiation standards for licensees</td>
<td>(9)</td>
</tr>
<tr>
<td>10 CFR 30</td>
<td>Licensing of by-product materials</td>
<td>(10)</td>
</tr>
<tr>
<td>10 CFR 40</td>
<td>Licensing for possession of source materials</td>
<td>(11)</td>
</tr>
<tr>
<td>10 CFR 50</td>
<td>Procedures for license termination and financial qualifications</td>
<td>(12)</td>
</tr>
<tr>
<td>10 CFR 51</td>
<td>Environmental Impact Statements for decommissioning</td>
<td>(13)</td>
</tr>
<tr>
<td>10 CFR 70</td>
<td>Effluent monitoring requirements for special nuclear materials</td>
<td>(14)</td>
</tr>
<tr>
<td>10 CFR 71</td>
<td>NRC regulations for packaging and shipment of radioactive materials</td>
<td>(15)</td>
</tr>
<tr>
<td>10 CFR 72</td>
<td>Licensing of independent spent fuel storage facilities</td>
<td>(54)</td>
</tr>
<tr>
<td>10 CFR 73</td>
<td>NRC regulations for protection of special nuclear materials in transit</td>
<td>(16)</td>
</tr>
<tr>
<td>10 CFR 110</td>
<td>Export/import of nuclear materials</td>
<td>(17)</td>
</tr>
<tr>
<td>10 CFR 150</td>
<td>Exemptions and agreement state licensing</td>
<td>(18)</td>
</tr>
<tr>
<td>40 CFR 50</td>
<td>National ambient air quality standards</td>
<td>(19)</td>
</tr>
<tr>
<td>40 CFR 141</td>
<td>Radioactivity standards for drinking water</td>
<td>(20)</td>
</tr>
<tr>
<td>40 CFR 1500</td>
<td>Council on Environmental Quality guidelines for environmental assessments and impact statements</td>
<td>(21)</td>
</tr>
<tr>
<td>49 CFR 170-199</td>
<td>Department of Transportation regulations for transport of hazardous materials</td>
<td>(22)</td>
</tr>
</tbody>
</table>
### TABLE 2.2-1. (Continued)

<table>
<thead>
<tr>
<th>Identification</th>
<th>Description</th>
<th>Reference Number</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B. Proposed Regulations and Other Related Guidance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fed. Register, Vol. 39, p. 32933</td>
<td>NRC proposed rule on transuranic waste disposal</td>
<td>(24)</td>
</tr>
<tr>
<td>NRC Branch Position (Draft, Rev. 1)</td>
<td>Low-level waste burial ground site closure and stabilization</td>
<td>(25)</td>
</tr>
<tr>
<td>Fed. Register, Vol. 43, p. 221</td>
<td>Proposed EPA criteria for radioactive wastes</td>
<td>(26)</td>
</tr>
<tr>
<td>Fed. Register, Vol. 43, p. 58946</td>
<td>EPA guidance for hazardous waste site control (proposed 40 CFR 250)</td>
<td>(27)</td>
</tr>
<tr>
<td>EPA 520/4-77-016</td>
<td>Proposed EPA guidance for transuranic elements in the environment</td>
<td>(28)</td>
</tr>
<tr>
<td>ANSI N13.12-1978</td>
<td>Release guidance for radioactive materials</td>
<td>(29)</td>
</tr>
<tr>
<td>NUREG-0240</td>
<td>NRC Low-Level Waste Management</td>
<td>(30)</td>
</tr>
<tr>
<td>NUREG-0436</td>
<td>Reevaluation plan for NRC decommissioning</td>
<td>(31)</td>
</tr>
<tr>
<td>NUREG-0456</td>
<td>Classification of radioactive wastes for disposal</td>
<td>(32)</td>
</tr>
<tr>
<td>NUREG-0590, Rev. 2</td>
<td>Thoughts on regulation changes for decommissioning</td>
<td>(33)</td>
</tr>
<tr>
<td>NUREG-0613</td>
<td>Residual radioactivity limits for decommissioning</td>
<td>(34)</td>
</tr>
<tr>
<td>NUREG/CR-0580</td>
<td>Evaluation of methods for low-level waste disposal</td>
<td>(35)</td>
</tr>
<tr>
<td>NUREG/CR-1005</td>
<td>Radwaste classification system</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 2.2-1. (Continued)

<table>
<thead>
<tr>
<th>Identification</th>
<th>Description</th>
<th>Reference Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reg. Guide 3.11.1, Rev. 1</td>
<td>Inspection and surveillance of retention systems at uranium mills</td>
<td>(36)</td>
</tr>
<tr>
<td>Reg. Guide 4.1, Rev. 1</td>
<td>Monitoring in environment of nuclear power plants</td>
<td>(3)</td>
</tr>
<tr>
<td>Reg. Guide 4.5</td>
<td>Sampling and analysis of plutonium in soil</td>
<td>(37)</td>
</tr>
<tr>
<td>Reg. Guide 4.6</td>
<td>Strontium-89, 90 analyses in environmental media</td>
<td>(38)</td>
</tr>
<tr>
<td>Reg. Guide 4.8</td>
<td>Environmental technical specifications for nuclear power plants</td>
<td>(39)</td>
</tr>
<tr>
<td>Reg. Guide 4.14, Rev. 1</td>
<td>Environmental monitoring at uranium mills</td>
<td>(5)</td>
</tr>
<tr>
<td>Reg. Guide 4.15, Rev. 1</td>
<td>Quality assurance for radiological monitoring programs</td>
<td>(40)</td>
</tr>
<tr>
<td>Reg. Guide 10.1, Rev. 3</td>
<td>NRC reporting requirements</td>
<td>(41)</td>
</tr>
<tr>
<td>Public Law 91-755</td>
<td>National Environmental Policy Act (NEPA)</td>
<td>(42)</td>
</tr>
<tr>
<td>Public Law 59-209</td>
<td>Federal Antiquity Act</td>
<td>(43)</td>
</tr>
<tr>
<td>Public Law 95-604</td>
<td>Uranium Mill Tailings Act</td>
<td>(44)</td>
</tr>
</tbody>
</table>

The Safe Drinking Water Act\(^{(46)}\) is intended to protect ground water sources for human consumption from contamination by "hazardous substances" injected into an aquifer. The possibility exists that EPA may consider any shallow waste disposal site permitting contamination to percolate into an aquifer as falling within the intent of the Act, and further, to include even low-level radioactivity as a "hazardous substance" for purposes of the Act.

Such an interpretation would differ from that provided by the Environmental Protection Agency (EPA) for the Resource Conservation and Recovery Act.\(^{(47)}\) This Act, which regulates nonradioactive hazardous solid wastes disposal, specifically excludes nuclear materials regulated under the Atomic
Energy Act (as amended). However, the EPA has indicated\(^{(27)}\) an intent to regulate certain mixed non-radioactive hazardous wastes (as defined in the Act) and low-level radioactive waste in the future. At this time, the RCRA does not govern LLWBG operations, provided appropriate controls have been placed on materials received for disposal.

It is the intent of the Clean Air Act (CAA)\(^{(48)}\) to regulate discharges of pollutants into the atmosphere. Generally, the Act is aimed at pollutant sources such as incinerators, odor-producing facilities, and steam plants, and is administered through the states or regional air pollution control districts. The Clean Air Act probably would not regulate the operation of a LLWBG with the possible exception of dust emissions arising from its operations. However, the 1977 amendments to the Act added radioactivity specifically as a pollutant to be regulated, and a letter of agreement between EPA and the NRC specifies that NRC will enforce through its regulations the radioactivity standards to be provided by EPA. These are not yet available, but would not be expected to impose any significant additional requirements on LLWBG operations.

2.2.3 State-Federal Interactions

Under Public Law 96-573, the states have been encouraged to assume responsibility for establishing and controlling additional low-level waste burial grounds through regional compacts.\(^{(49)}\) This is in keeping with earlier recommendations by a Task Force on Low-Level Radioactive Waste Disposal of the National Governors Association. Measures to implement such regional compacts are underway in a number of states, but specific siting and monitoring requirements will not be finalized for some months. Past experience with Agreement States indicates that monitoring programs meeting NRC requirements will be sufficient to meet state requirements.

2.3 EXPOSURE PATHWAY ANALYSIS

Exposure pathway analysis is commonly done for nuclear facilities\(^{(6,50,51)}\) and needs no elaboration here. Such analysis leads to the initial appraisal of potential routes of LLWBG contaminants to man illustrated in Figure 2.3-1.
FIGURE 2.3-1. Potential Pathways of Contaminants from LLWBG to Man
and itemized in Table 2.3-1. These include potential pathways that result from active site operations or are created by long-term migration of nuclides from the LLWBG site.

In exposure pathway analysis for LLWBGs, radiation doses to population groups of interest are calculated based on site-specific nuclide inventory and nuclide migration rate estimates. Other site-specific data requirements include operational history, site analysis (topographical, meteorological, hydrological), and demographic analysis (population distribution, as well as land usage and local dietary habits). If local data are not available, the parameter listings given in Regulatory Guide 1.109(53) may be used, but an effort should be made to verify such factors as growing season, irrigation practices, cattle feed sources, land productivity, and local game consumption. The dose calculation matrix of Soldat,(52) Figure 2.3-2, can be used; it affords a useful basis for checking the completeness of the dose evaluation process, particularly for the omission of any potential critical pathway.

In designing an environmental monitoring program at a proposed (or existing) LLWBG site, as a minimum, estimates of annual radiation doses and dose commitments from potential migration of the radionuclides buried or to be buried at the site should be made. These dose calculations should include the maximum-exposed (or critical) individual(a) and the total population living within 10 km of the site (or for a special population group living within 80 km who derive their water from ground or surface waters potentially affected by site operations). These calculations should include dose estimates for the whole body as well as any other critical body organ. Doses from all nuclides and exposure modes must of course be summed for each organ.

Summation of organ doses from all nuclides released will indicate which nuclides are the critical ones. For these nuclide(s), a retrace of the dose calculation procedure will reveal both the critical pathways and the media/nuclide possibilities for environmental surveillance.

(a) As per ICRP Publication No. 7,(1) the so-called critical individual may actually be a small group with homogeneous habits (and ages).
TABLE 2.3-1. Potential Routes and Most Probable Sources of Contamination to Man from Low-Level Waste Burial Grounds

<table>
<thead>
<tr>
<th>Potential Pathways</th>
<th>Upward Migration Through Capped Trenches</th>
<th>Downward Migration Through Permeable Base</th>
<th>Horizontal Migration from Trenches</th>
<th>No Migration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rainwater percolation into trenches with subsequent &quot;evaporation&quot;</td>
<td>Rain, water percolation</td>
<td>Transport of contaminants to surface by burrowing animals</td>
<td>Direct radiation during burials</td>
</tr>
<tr>
<td></td>
<td>Root systems &quot;tapping&quot; into trenches</td>
<td>Surface water percolation</td>
<td>Lateral transport in ground water</td>
<td>Direct radiation from loss of &quot;shielding&quot; (wind, floods; animals, human intrusion)</td>
</tr>
<tr>
<td></td>
<td>Evapotranspiration from vegetation</td>
<td></td>
<td>Transport through surface water overflow</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gaseous diffusion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probable Contaminants</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$^{3}$H, $^{14}$C</td>
<td>$^{3}$H, $^{106}$Ru</td>
<td>Activation products ($^{55}$Fe, $^{60}$Co, $^{63}$Ni)</td>
<td>$^{60}$Co</td>
</tr>
<tr>
<td></td>
<td>$^{60}$Co, $^{137}$Cs</td>
<td>$^{14}$NO$_{3}$ (nitrates)</td>
<td>Fission products ($^{3}$H, $^{90}$Sr, $^{137}$Cs)</td>
<td>$^{137}$Cs</td>
</tr>
</tbody>
</table>
FIGURE 2.3-2. Dose Calculation Matrix of Soldat(52) for Evaluating Potential Radionuclide Migration from a LLWBG Through Direct Radiation, Air, and Water Pathways
2.4 ENVIRONMENTAL SURVEILLANCE PROGRAM CRITERIA

Each commercial radioactive waste burial site is required, through the licensing process, to conduct an environmental monitoring program. This program will vary in extent and emphasis from the preoperational phase through decommissioning. The extent and frequency of the sampling may also differ for each burial ground, according to the characteristics of the particular site and the current phase of operations.

2.4.1 General Objectives

Environmental monitoring programs must be developed on a site-specific basis that takes into account the radionuclides and their burial locations at the site, site-specific critical pathways for the migration of contaminants to the environment, and potentially affected land-use and other human activities carried out near the site. The specific sampling schedules for the reference sites presented in Sections 4 through 7 of this document should serve as illustrations of environmental monitoring requirements, but should not be used verbatim to define requirements at specific existing or future sites. However, the accompanying text should be useful for formulating and implementing environmental surveillance programs at LLWBG sites.

The sampling programs described in Sections 4 through 7 may be carried out by the site operator, with periodic inspections of records and equipment performed by the appropriate regulatory agency. Analysis of environmental samples may be performed by a radioanalytical vendor that specializes in such work, or may be performed by the site(s) operator. Measured radioactivity levels exceeding a predetermined value (for other nuclear operations this has typically been twice that of the control sample) require notification of the site operator (if he's not performing the analyses) and applicable government agencies (at some higher level based on the Technical Specifications for the individual site). Additional samples and/or analyses to determine the specific radionuclides involved may also be required.

The importance of providing continuity and consistency of data from at least key parts of the environmental program cannot be overestimated. When new techniques and measurement locations are substituted in a program, sufficient overlapping data to provide continuity must be obtained.
Some provisions for pre-release (or pre-migration) data collection or at least deployment of operating equipment for use in nonroutine release evaluation is also an appropriate part of the routine program. When such an event occurs, the on and near site existence of functioning dosimeters, operating air samplers, and the availability of wells to sample ground water can be well worth some years of maintenance.

If non-radiological air and water quality measurements are being made in the site environment, coordination of both radiological and non-radiological programs should provide greater efficiency and lower overall cost. Use of common measurement or sample locations, if nothing else, may permit the use of one kind of measurement as a tracer for another.

2.4.2 General Environmental Surveillance Program Criteria

The ERDA Surveillance Guide\(^4\) proposed a set of general environmental monitoring program guidelines (see Table 3.2 in Reference 4) which have been modified and are proposed here for routine environmental surveillance at LLWBGs. These modified criteria are presented in Table 2.4-1. Application of these to an individual site requires that an adequate study of potential release mechanisms and exposure pathways therefrom shall have been made. It is believed that these criteria can be applied to LLWBG sites and can provide adequate data to satisfy members of the public and regulatory agencies with legitimate concerns. It should be fully understood that the proposed dose evaluation criteria do not define "as low as reasonably achievable" for environmental doses or needed controls.

Because potential nuclide migration from LLWBGs and the environmental media they affect may both vary with time, non-proportional and periodic grab sampling risk bias by being synchronized with some cyclic feature of the environment. Seasonal habits of people and animals can also result in non-relevant data from a uniform year-round program. Hunting is an excellent example, since terrestrial biota can be selective in what they eat and they select differently according to availability.
**TABLE 2.4-1. General Criteria for LLWBG Environmental Surveillance Programs(a)**

- A site-specific exposure pathway analysis should be performed for the potential radionuclide migration paths shown in Table 2.3-1; as a minimum, these should include the maximum-exposed individual and the population within a 10 km radius of centroid of the site:
  - for "normal" or routine operations (including occasional breaches of radwaste containers)
  - for "accident" or unusual events leading to release of or enhanced migration of buried radioactivity.

- The exposure pathway analysis should be documented, with data references and local assumptions clearly distinguished, and with critical nuclides, pathways, and population groups described.

- Every exposure pathway should be routinely measured which, as determined by the site-specific exposure pathway analysis, may contribute more than 1 mrem per year to the whole body or specific organ dose of individuals or critical population groups.(b)

- For critical pathways, a minimum of three locations should be routinely measured or sampled, including the location of greatest potential exposure and the nearest location of routine human occupancy.

- "Background" or "control" location measurements should be taken for every critical nuclide/pathway combination for which environmental measurements are made.

- Routine radioanalytical techniques should have minimum detection limits no higher than those equivalent to the 1 mrem/yr dose criterion.

- Sampling or measurement intervals for each critical nuclide/medium combination should not exceed twice the half-life of the nuclide to be measured or one year, whichever is less.

- Where significant periodic variations in environmental concentrations may be expected, samples or measurements should be either continuous or at an interval less than half the expected peak-to-peak interval.

- Gross radioactivity analyses should be used only as trend indicators, unless supporting analyses provide a reliable relationship to specific radionuclide concentrations.

- Dose calculations from direct environmental measurements should be based only on statistically significant differences between the point of measurement and background (or control) data. For this purpose, statistical comparisons should be made at the 95% confidence level.

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(a) Based in part on Table 3.2 of ERDA 77-24 (Ref 4).
(b) One-fifth of environmental dose limit proposed by NRC for decommissioning activities (Ref. 33).
Gross alpha and beta analyses of water and airborne particulates provide a more rapid and less expensive means of detecting changes in environmental radioactivity concentrations than specific nuclide analysis, and as such may be useful as trend or "action required" indicators. For other media, the use of gross activity analyses is of lesser value and is not recommended as a part of routine surveillance programs. However, a review of historical surveillance data, special studies of the local environment, and applicable literature studies may show the availability of indicator measurements which can be reliably related to population dose or at least individual dose pathways. If relevant data of this type are available, their use should be encouraged. As used here, trend indication includes those applications where continued verification of less than the measurement detection limit is normally expected. If isotopic ratios are relatively stable in local samples, gross activity may indeed be related in simple fashion to specific nuclide concentrations of interest and consequently to population dose. Use of such relationships for dose calculation should be based on repetitive verification.

2.4.3 Supplemental Program Components

Site history and current interests may indicate the need for inclusion of specific measurements to answer specific environmental questions, even when no other need is indicated. Some examples include sampling for tritium in streams and for various nuclides in ground water and in soils because of the possibility of impacts from the other sources, especially world-wide fallout. Followup actions may involve specific data collection involving temporary or permanent additions to the site monitoring program. Those responsible for environmental surveillance at every site will have the problem of integrating these needs into the routine program, especially with a view to substituting for other measurements that may already be part of the program without altering the continuity of established sample points and monitoring programs.

Additional samples and measurements taken specifically as part of the quality assurance program (discussed in Section 8) must also be integrated with the routine surveillance program, not only for greater efficiency but also to insure relevant results.
2.5 REFERENCES


32. G. D. Calkins, Thoughts on Regulation Changes for Decommissioning, NUREG-0590, Rev. 2 Draft, U.S. Nuclear Regulatory Commission, Washington, D.C., June 1980. **


42. Public Law (PL) 91-765, National Environmental Policy Act of 1969, 42 U.S. Code (USC), 4321 et seq.

43. PL 59-209 Federal Antiquity Act of 1906, 16 USC 431 et seq.


45. PL 92-500, Federal Water Pollution Control Act, 33 USC 466 et seq., as amended by PL 95-217, the Clean Water Act of 1977.


48. PL 95-95, Clean Air Act Amendments of 1977, 42 USC 7401 et seq.


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**Single copies are available free upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.
3.0 REFERENCE LOW-LEVEL WASTE BURIAL GROUNDS

Physical and operational characteristics of the six commercial low-level waste burial grounds (LLWBG) in the United States are summarized in Section 3 of the original document, NUREG/CR-0570. Because significant differences in physical and operational characteristics exist among those six sites and because further changes in operating practices and waste inventories may be expected, generic facilities were postulated based on the actual characteristics at existing commercial LLWBG sites.

Sections 3.1 through 3.4 summarize the physical and operational characteristics (including expected phases from preoperational to decommissioning), radioactive waste inventory, reference site characteristics, and critical exposure pathways to be considered in designing environmental surveillance programs at the reference burial grounds.

Additional operational and waste details for the reference sites are given in NUREG/CR-0570, from which much of the information presented in this Section has been liberally quoted, nearly verbatim, without specific reference thereto.

3.1 REFERENCE BURIAL GROUND CHARACTERISTICS

This section contains a summary of the generic (common) characteristics for the two reference sites, an arid western site and a humid eastern site, described in NUREG/CR-0570. Both the radwaste inventory and the population distribution for each site are identical while other parameters are chosen to be representative of existing or proposed practices.

The climate, geology, and hydrology of the reference sites (Western--Richland, WA; Eastern--Sheffield, IL) are described in detail in Section 7 of NUREG/CR-0570. However, as described in NUREG/CR-0570, some of the physical and operational characteristics of the reference LLWBGs are not the same as those for the burial grounds actually located at the specific sites. The key assumptions/bases listed in NUREG/CR-0570 to describe the reference LLWBGs are summarized in Table 3.1-1.
TABLE 3.1-1. Characteristics of Reference Low-Level Waste Burial Ground\(^{(a, b)}\)

- 30 years continuous operation of LLWBG (waste receipt, burial and covering) is assumed.
- Current trench construction, filling and capping practices are used.
- Site operations/preparation for decommissioning occur concurrently.
- Radwaste inventory is 60% fuel-cycle, 40% non-fuel-cycle waste.
- Waste volume contains less than 1% free liquids.
- Outer waste containers are nonradioactive.
- Wastes are packaged according to current DOT standards.
- Ground surface is free of radioactive contamination at time decommissioning begins.
- No wastes are unburied at time decommissioning begins.
- All burial trenches are capped.
- Trench caps are graded and seeded to control drainage.
- Radwaste transportation to site is by truck.
- Decommissioning phase includes waste burial trenches only.

\(^{(a)}\) Adapted from Section 7.1 of NUREG/CR-0570.
\(^{(b)}\) The chemical or pyrophoric hazards of wastes buried at LLWBGs are not specifically considered in this report.

3.1.1 Description of Reference Burial Grounds

The generic or "reference" burial ground is assumed to be located on an upland area of generally flat or gently rolling terrain as shown in the generalized cross sectional view of Figure 3.1-1. The total site area is 70 hectares \((7 \times 10^5 \text{ m}^2)\), of which about 50 hectares contain burial trenches. The remaining land area is used for buildings, access roads, and a 50 m wide
exclusion area around the site perimeter between the trench area and the site fence (1.8 m high chain-link topped with a three-strand barbed wire outrider). The chain-link fence gate is closed and locked at the end of each working day during burial ground operations.

The total site capacity for waste is about $1.5 \times 10^6$ m$^3$, contained in 180 burial trenches. The normal trenches are assumed to be 150 m long, 15 m wide at the top, sloping to 10 m wide at the bottom, and 7.5 m deep. Each trench is filled with waste to within 1 m of the ground surface. The top 1 m of trench is reserved for fill soil. When a trench is completely filled, it is covered with a trench cap of soil mounded to 1 m above grade. The effective waste volume per trench is about 8300 m$^3$. It is assumed that six trenches are filled during each of 30 years of operation of the burial ground.

At some commercial sites, high beta-gamma activity waste is buried separately from other radioactive waste in smaller dry wells, pits, or slit trenches. Should exhumation be required as part of decommissioning operations, the reference burial ground is assumed to include 10 slit trenches containing these highly activated non-fuel-bearing wastes. They are packaged in steel liners and transported to the trench in heavily shielded reusable casks from which the liner is removed in the trench. Other than the special shielding precautions during handling and the greater soil overburden after emplacement,

\[ \text{FIGURE 3.1-1. Generalized Cross Section of a Low-Level Waste Burial Site} \]
the trench capping operations are similar to those for all other waste buried at a LLWBG. A typical slit trench is 150 m long, 1.2 m wide, and 6 m deep, and contains 150 m³ of waste packaged in 90 canisters.

3.1.2 Construction and Filling of Burial Trenches

Open trenches are used for burial at both the western and eastern sites. Primarily because of the much heavier precipitation at the eastern site, trench construction details and trench capping procedures are more complex at the eastern site than at the western site.

Because of the low rainfall and highly permeable sediments at the western site, no special precautions are required to prevent standing water from accumulating in a trench or to prevent contact of the waste with water. Stand pipes are installed for monitoring purposes and wastes are covered with soil on an irregular basis, up to several days later if soil shielding is not needed. The final trench cover at the western site is excavated earth fill; no special attempt is made to compact the fill or to seal the trench.

Construction details for a typical trench at the eastern site are similar, but include a one degree (1°) slope in the bottom of trenches from end to end and from one side toward a gravel-filled French drain. The French drain runs the entire trench length on the low elevation side to provide for collection of any liquid drainage that might occur and the trench bottom is covered with a 0.6-m layer of sand. A gravel-filled sump is provided at the low corner of each trench. Three stand pipes are installed in these trenches, one at each end and one at the midpoint to check for moisture collection. In the event that liquids are observed, they are pumped out, solidified, and buried.

To minimize contact with moisture at the eastern site, the waste is covered with soil as it is placed in a trench, and the soil cover is compacted using heavy rolling equipment. When a trench is completely filled, it is covered with soil, mounded and compacted to 1 m above the land surface using impermeable soils with high clay content. The trench cover is then seeded with shallow-rooted ground cover plant species to help control erosion. Drainage fields may also be constructed around the mounded trenches.
At both sites, waste packages are emplaced by random crane lowering from above a trench, beginning at the high end. During the early years of commercial burial ground operations, random dumping of wastes was employed. Current burial ground operating procedure provides for some segregation of waste packages, with cement caissons, steel cask liners, and large plywood boxes being stacked and other smaller waste packages, including steel drums, being randomly placed into trenches. For high beta-gamma activity wastes, burial operations consist of placing the shielding cask vertically in a slit trench, unloading the cask from the top end, laying the inner waste package horizontally in the bottom of the trench, removing the cask, and backfilling earthen cover over the waste package. Three layers of waste packages and associated intervening layers of soil, including the trench overburden, comprise the finished trench.

A record of the wastes buried in individual trenches is kept at each burial site. As part of this record, the locations where special nuclear material is buried are recorded on trench grid maps. Recently some sites have begun recording the burial locations of all waste shipments on trench grid maps. These maps permit the positions of individual burials to be designated to within about 10 m.

3.2 REFERENCE WASTE INVENTORY

The reference waste inventory in the burial trenches is assumed to be comprised of 40% (by volume) non-fuel-cycle waste and 60% reactor fuel-cycle waste, with a total waste volume per trench of 8300 m$^3$.

The non-fuel-cycle waste comes mainly from hospitals, medical schools, and universities and colleges. It includes trash paper, packing material, protective clothing, broken glassware, plastics, expended scintillation cocktail and vials, animal carcasses, obsolete equipment, and building rubble. The waste is estimated to have an average specific activity of less than 0.1 Ci/m$^3$, principally $^3$H and $^{14}$C.

Fuel-cycle waste includes many of these same categories, as well as higher activity waste such as spent ion-exchange resins, filters, filter sludges, solidified evaporator bottoms, shielding, piping, instrumentation, control
rods, and neutron-activated materials. Most of this waste (approximately 98%) comes from nuclear reactor operations. The principal isotopes in the waste include the activation products $^{55}$Fe, $^{60}$Co, and $^{63}$Ni (from LWR decommissioning), and the fission products $^{134}$Cs and $^{137}$Cs.

The specific radionuclide inventory for the generic LLWBGs was prepared by NRC staff members as itemized in Appendix B of NUREG/CR-0570. The inventory is normalized by assuming a byproduct specific activity of 9 Ci/m$^3$ at the time of waste burial. To obtain the total inventory at the time of site closure, the inventory in individual trenches is decayed, using the assumption that six trenches are filled during each of the 30 years of burial ground operation. Allowance is made for the ingrowth of radioactive daughters not present in the original inventory.

Table 3.2-1 lists both the as-buried inventory for a single trench (i.e., the inventory at the time of waste burial) and the total inventory of all the trenches at the time of site closure. The total trench inventory assumes 1/30 of the waste buried in each of the 30 years of burial ground operation, allowing also for radioactive decay and ingrowth of radioactive daughters.

Waste in the slit trenches consists mainly of non-fuel-bearing components from LWRs packaged in steel canisters. Typical activities at the time of waste burial are in the range of 1000 to 5000 Ci/m$^3$ or 1.5 to $7.5 \times 10^5$ Ci total, consisting mainly of $^{55}$Fe and $^{60}$Co. The assumed fractional radionuclide inventory for slit trenches is shown in Table 3.2-2.

3.3 REFERENCE SITE ENVIRONMENTS

The generic burial ground is postulated to be located on two reference sites, an arid western site and a humid eastern site. A generic population distribution that is common to both sites is also assumed, with relatively low population density out to 16 km. Higher population densities are located in the 16 to 80 km distances with an 80 km population of 3.5 million. Details of the assumed population distribution are given in Table A.3-1, Vol. 2 of NUREG/CR-0570. For both sites the nearest residence is located within 1.6 km of the site. The climate, geology, and hydrology of the western and eastern
## TABLE 3.2-1. Radionuclide Inventory for Reference LLWBG(a)

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Half Life (years)</th>
<th>Average Activity in Waste (Ci/m³)</th>
<th>As-Buried Activity per Trench (Ci)</th>
<th>Total Burial Ground Inventory at Time of Site Closure (Ci)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3H</td>
<td>1.2 x 10¹</td>
<td>1.6 x 10⁻¹</td>
<td>1.3 x 10³</td>
<td>1.1 x 10⁵</td>
</tr>
<tr>
<td>14C</td>
<td>5.7 x 10³</td>
<td>5.0 x 10⁻¹</td>
<td>4.2 x 10³</td>
<td>7.6 x 10³</td>
</tr>
<tr>
<td>51Cr</td>
<td>7.6 x 10⁻¹</td>
<td>5.7 x 10⁻¹</td>
<td>4.7 x 10³</td>
<td>3.0 x 10²</td>
</tr>
<tr>
<td>54Mn</td>
<td>8.3 x 10⁻¹</td>
<td>3.3 x 10⁻¹</td>
<td>2.7 x 10³</td>
<td>1.9 x 10⁴</td>
</tr>
<tr>
<td>55Fe</td>
<td>2.6 x 10⁰</td>
<td>5.7 x 10⁻¹</td>
<td>4.7 x 10³</td>
<td>1.0 x 10⁵</td>
</tr>
<tr>
<td>58Co</td>
<td>2.0 x 10⁻¹</td>
<td>5.7 x 10⁻¹</td>
<td>4.7 x 10³</td>
<td>5.2 x 10³</td>
</tr>
<tr>
<td>60Co</td>
<td>5.3 x 10⁰</td>
<td>1.7 x 10⁰</td>
<td>1.4 x 10⁴</td>
<td>6.2 x 10⁵</td>
</tr>
<tr>
<td>63Ni</td>
<td>9.2 x 10¹</td>
<td>3.2 x 10⁰</td>
<td>1.4 x 10⁴</td>
<td>2.5 x 10⁴</td>
</tr>
<tr>
<td>65Zn</td>
<td>6.7 x 10⁻¹</td>
<td>2.7 x 10⁻²</td>
<td>2.5 x 10⁵</td>
<td>1.2 x 10³</td>
</tr>
<tr>
<td>90Sr</td>
<td>2.8 x 10¹</td>
<td>5.4 x 10⁻³</td>
<td>5.3 x 10³</td>
<td>6.7 x 10³</td>
</tr>
<tr>
<td>90Y(b)</td>
<td>7.3 x 10⁻³</td>
<td>---</td>
<td>2.2 x 10²</td>
<td>6.7 x 10³</td>
</tr>
<tr>
<td>95Zr</td>
<td>1.8 x 10⁻¹</td>
<td>2.7 x 10⁻²</td>
<td>2.0 x 10²</td>
<td>2.0 x 10²</td>
</tr>
<tr>
<td>99Tc</td>
<td>2.1 x 10⁵</td>
<td>4.3 x 10⁻⁵</td>
<td>3.6 x 10⁻¹</td>
<td>6.5 x 10⁴</td>
</tr>
<tr>
<td>106Ru</td>
<td>1.0 x 10⁵</td>
<td>2.7 x 10⁻²</td>
<td>----</td>
<td>1.9 x 10³</td>
</tr>
<tr>
<td>106Rb(d)</td>
<td>9.5 x 10⁻⁷</td>
<td>---</td>
<td>1.9 x 10³</td>
<td></td>
</tr>
<tr>
<td>124Sb</td>
<td>1.6 x 10⁻¹</td>
<td>6.6 x 10⁻³</td>
<td>5.5 x 10¹</td>
<td>3.8 x 10¹</td>
</tr>
<tr>
<td>125Sb</td>
<td>2.7 x 10⁰</td>
<td>6.6 x 10⁻³</td>
<td>5.5 x 10¹</td>
<td>1.3 x 10³</td>
</tr>
<tr>
<td>129I</td>
<td>1.7 x 10⁷</td>
<td>8.5 x 10⁻⁶</td>
<td>7.0 x 10⁻²</td>
<td>1.3 x 10⁴</td>
</tr>
<tr>
<td>134Cs</td>
<td>2.0 x 10⁰</td>
<td>6.4 x 10⁻¹</td>
<td>5.3 x 10³</td>
<td>9.4 x 10⁴</td>
</tr>
<tr>
<td>135Cs</td>
<td>3.0 x 10⁶</td>
<td>4.3 x 10⁻⁵</td>
<td>3.6 x 10⁻¹</td>
<td>6.8 x 10²</td>
</tr>
<tr>
<td>137Cs</td>
<td>3.0 x 10¹</td>
<td>1.1 x 10⁰</td>
<td>9.1 x 10³</td>
<td>1.2 x 10⁶</td>
</tr>
<tr>
<td>144Ce</td>
<td>7.8 x 10⁻¹</td>
<td>2.7 x 10⁻²</td>
<td>2.2 x 10²</td>
<td>1.4 x 10³</td>
</tr>
<tr>
<td>144Pr(b)</td>
<td>3.0 x 10⁻⁵</td>
<td>---</td>
<td>1.4 x 10³</td>
<td></td>
</tr>
<tr>
<td>222Rn(c)</td>
<td>1.0 x 10⁻²</td>
<td>---</td>
<td>2.1 x 10²</td>
<td></td>
</tr>
<tr>
<td>222Rn</td>
<td>1.6 x 10³</td>
<td>1.5 x 10⁻⁴</td>
<td>1.2 x 10⁰</td>
<td>2.1 x 10²</td>
</tr>
<tr>
<td>230Th</td>
<td>8.0 x 10⁴</td>
<td>9.4 x 10⁻⁵</td>
<td>7.8 x 10⁻¹</td>
<td>1.4 x 10²</td>
</tr>
<tr>
<td>232Th</td>
<td>1.4 x 10¹⁰</td>
<td>1.1 x 10⁻⁵</td>
<td>9.1 x 10⁻²</td>
<td>1.6 x 10¹</td>
</tr>
<tr>
<td>235U</td>
<td>7.1 x 10⁸</td>
<td>4.3 x 10⁻⁵</td>
<td>3.5 x 10⁻¹</td>
<td>6.5 x 10¹</td>
</tr>
<tr>
<td>238U</td>
<td>4.5 x 10⁹</td>
<td>9.4 x 10⁻⁴</td>
<td>7.8 x 10⁰</td>
<td>1.4 x 10³</td>
</tr>
<tr>
<td>237Np</td>
<td>2.1 x 10⁶</td>
<td>6.1 x 10⁻⁸</td>
<td>5.1 x 10⁻⁴</td>
<td>9.2 x 10⁻²</td>
</tr>
<tr>
<td>238Pu</td>
<td>8.6 x 10¹¹</td>
<td>4.3 x 10⁻⁴</td>
<td>3.6 x 10⁰</td>
<td>6.0 x 10²</td>
</tr>
<tr>
<td>239Pu</td>
<td>2.4 x 10⁷</td>
<td>5.7 x 10⁻⁵</td>
<td>4.7 x 10⁻¹</td>
<td>8.5 x 10¹</td>
</tr>
<tr>
<td>240Pu</td>
<td>6.6 x 10³</td>
<td>8.9 x 10⁻⁵</td>
<td>7.4 x 10⁻¹</td>
<td>1.3 x 10²</td>
</tr>
<tr>
<td>241Pu</td>
<td>1.3 x 10¹</td>
<td>2.2 x 10⁻²</td>
<td>1.8 x 10²</td>
<td>1.6 x 10⁴</td>
</tr>
<tr>
<td>242Pu</td>
<td>3.8 x 10⁵</td>
<td>3.2 x 10⁻⁷</td>
<td>2.6 x 10⁻³</td>
<td>4.7 x 10⁻¹</td>
</tr>
<tr>
<td>241Am</td>
<td>4.6 x 10²</td>
<td>4.0 x 10⁻⁴</td>
<td>3.3 x 10⁻¹</td>
<td>5.1 x 10²</td>
</tr>
<tr>
<td>243Am</td>
<td>8.0 x 10³</td>
<td>2.8 x 10⁻⁶</td>
<td>2.3 x 10⁻²</td>
<td>4.1 x 10⁰</td>
</tr>
<tr>
<td>242Cm</td>
<td>4.4 x 10⁻¹</td>
<td>3.3 x 10⁻³</td>
<td>2.7 x 10⁻¹</td>
<td>9.4 x 10⁻¹</td>
</tr>
<tr>
<td>244Cm</td>
<td>1.6 x 10¹</td>
<td>2.5 x 10⁻⁴</td>
<td>2.1 x 10⁰</td>
<td>2.2 x 10²</td>
</tr>
</tbody>
</table>

(a) From Table 9.3-3 in NUREG/CR-0570.
(b) Short-lived daughter of parent with same mass number.
(c) Short-lived daughter of 226Ra.

3-7
TABLE 3.2-2. Fractional Radionuclide Inventory for a Slit Trench\(^{(a)}\) (at time of burial)

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Half Life (Years)</th>
<th>Fractional Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>(^{54})Mn</td>
<td>8.3 x 10(^{-1})</td>
<td>4.0 x 10(^{-2})</td>
</tr>
<tr>
<td>(^{55})Fe</td>
<td>2.5 x 10(^{0})</td>
<td>5.0 x 10(^{-1})</td>
</tr>
<tr>
<td>(^{57})Fe</td>
<td>1.2 x 10(^{-1})</td>
<td>2.0 x 10(^{-2})</td>
</tr>
<tr>
<td>(^{58})Co</td>
<td>2.0 x 10(^{-1})</td>
<td>5.0 x 10(^{-2})</td>
</tr>
<tr>
<td>(^{60})Co</td>
<td>5.3 x 10(^{0})</td>
<td>3.5 x 10(^{-1})</td>
</tr>
<tr>
<td>(^{59})Ni</td>
<td>8.0 x 10(^{4})</td>
<td>3.0 x 10(^{-4})</td>
</tr>
<tr>
<td>(^{63})Ni</td>
<td>9.2 x 10(^{1})</td>
<td>4.0 x 10(^{-2})</td>
</tr>
</tbody>
</table>

\(^{(a)}\) From Table 7.3-4 in NUREG/CR-0170.

sites are typical of Richland, Washington, and Sheffield, Illinois, respectively. Specific environmental characteristics of the reference sites are summarized in Table 3.3-1.

Since water constitutes a major potential transport mechanism for the migration of radioactivity from LLWBGs, hydrologic factors are emphasized. At both sites there is the potential for surface runoff to carry contamination offsite, but this factor is generally only of importance at the more rainy eastern site. At either site the potential exists for interstitial hydraulic conductivity and adsorptive capacity to be bypassed by flow along subsurface sand and gravel lenses, joints, and fractures. The potential for this to occur must be determined on a site-specific basis. Hence, the possible presence of lenses, joints, and fractures is not specifically included in these reference site descriptions.

The western site is semi-arid with summers marked by very low precipitation and high temperatures, resulting in soil moisture deficiencies. Occasional periods of high winds are accompanied by blowing sand. Additional characteristics include:

- low annual precipitation, with evaporation slightly exceeding precipitation
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Western Site</th>
<th>Eastern Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Annual Precipitation</td>
<td>160 mm</td>
<td>900 mm</td>
</tr>
<tr>
<td>Average Annual Evaporation</td>
<td>165 mm (a)</td>
<td>660 mm</td>
</tr>
<tr>
<td>Surface Material</td>
<td>Silt, sand, gravel</td>
<td>Loess, till, clay</td>
</tr>
<tr>
<td>Bedrock Material</td>
<td>Basalt</td>
<td>sand, gravel</td>
</tr>
<tr>
<td>Surface Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximity</td>
<td>16 km</td>
<td>1 km</td>
</tr>
<tr>
<td>Flow Rate</td>
<td>$3.4 \times 10^6 \text{ l/sec}$</td>
<td>$220 \text{ l/sec}$</td>
</tr>
<tr>
<td>Ground Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximity (depth to)</td>
<td>60 m</td>
<td>10 m</td>
</tr>
<tr>
<td>Gradient</td>
<td>0.18%</td>
<td>5%</td>
</tr>
<tr>
<td>Average Velocity</td>
<td>200 m/yr</td>
<td>3.7 m/yr</td>
</tr>
<tr>
<td>Cation Exchange Capacity</td>
<td>20 to 80 meq/0.1 kg</td>
<td>20 to 80 meq/0.1 kg</td>
</tr>
<tr>
<td>Hydraulic Conductivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>$7 \times 10^{-6} \text{ m/sec}$</td>
<td>---</td>
</tr>
<tr>
<td>Loess</td>
<td>---</td>
<td>$2 \times 10^{-8} \text{ m/sec}$</td>
</tr>
<tr>
<td>Till</td>
<td>---</td>
<td>$3 \times 10^{-8} \text{ m/sec}$</td>
</tr>
<tr>
<td>Sand</td>
<td>$1 \times 10^{-4} \text{ m/sec}$</td>
<td>$3 \times 10^{-5} \text{ m/sec}$</td>
</tr>
<tr>
<td>Shale</td>
<td>---</td>
<td>$2 \times 10^{-7} \text{ m/sec}$</td>
</tr>
<tr>
<td>Gravel</td>
<td>$3 \times 10^{-4} \text{ m/sec}$</td>
<td>---</td>
</tr>
<tr>
<td>Effective Porosity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>0.20</td>
<td>---</td>
</tr>
<tr>
<td>Loess</td>
<td>---</td>
<td>0.20</td>
</tr>
<tr>
<td>Till</td>
<td>---</td>
<td>0.20</td>
</tr>
<tr>
<td>Sand</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>Shale</td>
<td>0.15</td>
<td>---</td>
</tr>
<tr>
<td>Gravel</td>
<td>0.35</td>
<td>---</td>
</tr>
<tr>
<td>$K_d$ (b)</td>
<td></td>
<td>350 $\mu$/kg</td>
</tr>
<tr>
<td>Cobalt</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Strontium</td>
<td>20 $\mu$/kg</td>
<td>10 $\mu$/kg</td>
</tr>
<tr>
<td>Ruthenium</td>
<td>400 $\mu$/kg</td>
<td></td>
</tr>
<tr>
<td>Cesium</td>
<td>100 $\mu$/kg</td>
<td>40 $\mu$/kg</td>
</tr>
<tr>
<td>Uranium</td>
<td>20 $\mu$/kg</td>
<td></td>
</tr>
<tr>
<td>Plutonium</td>
<td>200 $\mu$/kg</td>
<td></td>
</tr>
<tr>
<td>Americium</td>
<td>1200 $\mu$/kg</td>
<td></td>
</tr>
</tbody>
</table>

(a) It is believed that essentially all (here shown slightly greater than, but not considered statistically significant) precipitation returns to the atmosphere by evaporation (and evapotranspiration), based on measurements made since 1971 (see Reference 4).

(b) Distribution coefficients, $K_d$, for isotopes reported in the literature. An expanded set of distribution coefficients is given in Table C.2-3, Volume 2 of NUREG/CR-0570.
- 60 m depth to ground water
- soil with moderate-to-high hydraulic conductivity
- relatively long distance from burial ground to point of ground-water discharge into surface streams

The eastern site has a continental climate with a wide range of temperatures through the year. Summers are characterized by intense heat and high humidity, and winters by extreme cold with occasional heavy snowfall and moderate-to-high winds. Additional characteristics include:

- high annual precipitation
- only 10 m depth to ground water
- soil with low hydraulic conductivity
- relatively short distance from burial ground to point of ground-water discharge into surface streams

Figures 3.3-1 and 3.3-2 show the contrasting mean monthly precipitation and wind speeds for the respective sites.

3.4 POTENTIAL CRITICAL EXPOSURE PATHWAYS

Since the basic radiation standards are given in terms of dose to people, it is desirable to estimate the potential radiation exposure of the public from activities at the reference LLWBGs. The potential exposures from radioactive waste buried at the reference sites can occur either from individuals encountering the waste directly or from the waste migrating from its burial (or intended burial) location into man's environment. The migration of radionuclides from LLWBGs has been investigated by several groups\(^5\),\(^6\),\(^7\) and Rogers\(^8\) proposed a radwaste classification system based on radiation dose potential. Even though the critical pathways may be much the same for the two reference sites, the chain of events leading to human exposure may differ.

Because of the uncertainties in radionuclide transport models and in parameters (e.g., hydraulic conductivity, distribution coefficients, leach times, etc.) used with the models, a generally conservative approach was used
FIGURE 3.3-1. Mean Monthly Precipitation for the Reference Sites

FIGURE 3.3-2. Mean Monthly Wind Speed for the Reference Sites
here to predict possible pathways and to estimate relative maximum-exposed individual doses. It must be emphasized that the conclusions reached here apply specifically to the reference sites and to the assumed radionuclide inventory. The methodology presented in the original report, NUREG/CR-0570, should be reapplied to estimate radiation doses and to predict critical pathways for each burial ground that has a different inventory and different site characteristics, using the site-specific parameters for each new burial ground.

Potential doses to a maximum-exposed individual who lives and works near either the western or eastern sites were estimated. One of the key assumptions for the reference sites (Section 2) is that the radioactive wastes are received in containers free of surface contamination. However, past experience\(^5,6,8^\) has shown that surface contamination of soils (with subsequent resuspension) either from contaminated or ruptured containers is one of the key means whereby radioactive contaminants are released to the environment during the operational phase of the burial grounds. Therefore airborne particulates are postulated to be a potential critical pathway for both reference sites during the operational phase (though the path is not one considered due to routine operational activities).

Direct radiation is considered the predominant path during normal operations (i.e., with no spills or ruptures of waste containers) and in a manner similar to airborne particulates is monitored at both reference sites as a potential critical exposure pathway.

Environmental characteristics provided for the reference sites indicate that ground-water flow velocity for the arid and humid LLWBGs differ markedly. Based on the hydrologic information presented in Table 3.3-2, if contaminants reach the aquifer the possibility of contaminated ground water migrating significantly (\(\sim 500 \text{ m}\)) beyond the boundaries of the humid site are minimal during the 30 year lifetime of the humid LLWBG. The arid site, however, with its greater ground-water flow rate might result in contaminants in ground water beyond its fenceline during its operational lifetime. However, disposal practices limiting waste-volume to less than 1% free liquids are such to preclude downward migration of contaminants, and hence they should not reach

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the aquifer at the arid site. Therefore, during the operational phase, ground water is not predicted to be a potential critical path for the arid western site or the humid eastern site.

Ingestion of foodstuffs is not predicted to be a critical path during the operational phase for the following reasons: no vegetation suitable for human consumption is grown on the site during this period; the water used to irrigate local crops is uncontaminated during this time; and the presence of edible wildlife onsite is minimized due to burial operations and the almost constant human presence. Therefore the potential for the contamination of flora and fauna with subsequent transmittal to man is considered small.

After all nuclear waste has been buried site closure activities such as site/waste stabilization may require the movement of large quantities of soil to cover the trenches. If no leakage or rupture of waste containers has occurred, then under routine operations the surface should be free of removable or resuspendable contamination (as noted above and in the key assumptions of Section 7.1 in NUREG/CR-0570). Under these circumstances the most significant pathway would be from ground water contaminated by leaking or migrating waste. However, experience at existing burial grounds\(^\text{5,6,9}\) has shown that the potential for contamination of soil exceeds the potential for contaminating ground water. Monitoring of air particulate activity as an indication of resuspended contaminants is therefore considered necessary during site closure operations.

Direct radiation is not considered a critical pathway during this portion of the post-operational phase for either reference site, since site closure activities add shielding to the already capped trenches. Similarly, ingestion of animals or other foodstuffs is not considered to represent a critical pathway for the reasons addressed during the operational period (i.e., the site is still "off-limits" to the populace and the earth moving operations should preclude the survival or presence of most plants and animals).

No waste burial or earth moving activities are planned or expected during the short-term post-operational period. Instead this time is used to evaluate
the effectiveness of site/waste stabilization and other site closure operations. The net result is that during this period airborne particulate contamination and direct radiation are of little concern as exposure pathways. Experience has again shown that in this time of minimum human activity/presence intrusion by burrowing animals may be one of the primary means of transmitting buried contaminants to man's environment. Ground-water contamination at this point in time is predicted to be minimal for the humid eastern site and of even less consequence at the arid western site.

The presence of vegetation growing over the capped trenches is a possibility in the short-term care period, as it is assumed that little vegetative control will be exercised over the site at this time. Vegetation contaminated either through surface deposition or root uptake are a source of food to wildlife inhabiting the site and can transmit contamination through ingestion. Direct consumption of vegetation growing onsite by members of the public is not considered likely at this time, as their access to the site is restricted during the short-term care period.

As with the short-term care period, no waste burial or earth moving activities are expected during long-term care. The presence of site-related personnel on the site is minimal, probably only during the visits to look for evidence of intrusion, subsidence of the backfilled areas and trench caps, and general site appearance. Access to the site is still limited, but with only periodic surveillance, continuous control of access into the exclusion area of the site is difficult to ensure. Hence, some migration of buried radioactivity through deliberate intrusion by man cannot be ruled out, yet this is not expected to represent a significant pathway. On the other hand, if waste migration is to occur, it might do so more likely through animal/vegetation intrusion into the waste followed by consumption by man or through man's use of contaminated ground water.

If waste exhumation is required as part of the site decommissioning, these activities would be somewhat similar to those during waste burials, but with a greater potential for uncontained radionuclides. During this period direct radiation (from lack of shielding) and inhalation of resuspended material (as
a result of earth moving operations) are considered to be the most probable critical pathways of radiation to man. Other potential pathways, such as direct injection to ground water or surface run-off to streams (drinking water supplies, especially at the humid site), are deemed to be of much lower probability, except for an extreme climatic event. These latter pathways are shown parenthetically in Table 3.4.1.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Arid Western Site</th>
<th>Humid Eastern Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations</td>
<td>• Inhalation of Airborne Particulates</td>
<td>• Inhalation of Airborne Particulates</td>
</tr>
<tr>
<td></td>
<td>• Direct Radiation</td>
<td>• Direct Radiation</td>
</tr>
<tr>
<td>Post-Operations</td>
<td>• Inhalation of Resuspended Particulates</td>
<td>• Inhalation of Resuspended Particulates</td>
</tr>
<tr>
<td></td>
<td>• Ingestion of Ground Water</td>
<td>• Ingestion of Ground Water (or Surface Water)</td>
</tr>
<tr>
<td>Site Closure</td>
<td>• Intrusion by Animals</td>
<td>• Intrusion by Animals</td>
</tr>
<tr>
<td></td>
<td>• Intrusion by Vegetation</td>
<td>• Intrusion by Vegetation</td>
</tr>
<tr>
<td></td>
<td>• Ingestion of Ground Water</td>
<td>• Ingestion of Ground Water (or Surface Water)</td>
</tr>
<tr>
<td>Short-Term Care</td>
<td>• Intrusion by Animals</td>
<td>• Intrusion by Animals</td>
</tr>
<tr>
<td></td>
<td>• Intrusion by Vegetation</td>
<td>• Intrusion by Vegetation</td>
</tr>
<tr>
<td></td>
<td>• Ingestion of Ground Water</td>
<td>• Ingestion of Ground Water (or Surface Water)</td>
</tr>
<tr>
<td>Long-Term Care</td>
<td>• Intrusion by Animals</td>
<td>• Intrusion by Animals</td>
</tr>
<tr>
<td></td>
<td>• Intrusion by Vegetation</td>
<td>• Intrusion by Vegetation</td>
</tr>
<tr>
<td></td>
<td>• Ingestion of Ground Water</td>
<td>• Ingestion of Ground Water (or Surface Water)</td>
</tr>
<tr>
<td>Decommissioning</td>
<td>• Inhalation of Resuspended Particulates</td>
<td>• Inhalation of Resuspended Particulates</td>
</tr>
<tr>
<td>Waste Exhumation</td>
<td>• Direct Radiation</td>
<td>• Direct Radiation</td>
</tr>
<tr>
<td></td>
<td>• (Ingestion of Ground Water)</td>
<td>• (Ingestion of Ground or Surface Waters)</td>
</tr>
</tbody>
</table>

TABLE 3.4-1. Potential Critical Radiological Pathways for Reference Low-Level Waste Burial Grounds
3.6 REFERENCES


*Available for purchase from the NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, DC 20555 and/or the National Technical Information Service, Springfield, VA 22161.
4.0 PREOPERATIONAL ENVIRONMENTAL SURVEILLANCE

An environmental surveillance program requires sampling or directly measuring those media that may provide an exposure pathway to the public. Considerable care must be taken in designing a program to provide one that is both technically sound and sufficiently broad. The programs developed for the reference sites are based both on the general criteria presented in Table 2.4-1 which are not site specific and the potential routes to man and specific critical pathways/nuclides shown in Table 3.4-1.

The preoperational monitoring program is the most extensive of the monitoring programs to be performed at the reference low-level waste burial grounds. Clearly stated goals, such as those general objectives listed in Table 2.1-1, need to be formulated before program design can begin.

4.1 OBJECTIVES, TIMING, AND DURATION OF A PREOPERATIONAL MONITORING PROGRAM

At least one year prior to any major trench construction, a preoperational environmental surveillance program should be conducted to provide baseline data on the proposed LLWBG and its surroundings, to determine potential critical pathways to man; and to provide a "shakedown" period for equipment, personnel, techniques, and sampling/strategy to be evaluated.

The preoperational phase of the environmental surveillance program should be considered completed just prior to receipt of waste.

4.2 MEDIA AND MEASUREMENTS

Critical pathways have been postulated for the various stages of the reference LLWBGs and are summarized in Table 3.4-1. The expectation that a particular medium could become a critical pathway at some stage in the life of the LLWBG is sufficient reason to monitor it during the preoperational phase. Hence, it becomes necessary to sample each pathway, even though the relative importance of those pathways changes over the lifetime of each burial ground. In this way, multiple baseline levels can be established for anticipated future need. At some later date this information can be used as a reference and the impact of the LLWBG evaluated.
The major objective of the preoperational environmental surveillance program remains to provide reliable information that can be used to predict or assess the impact of the LLWBG on man. To a great extent this objective is attained through selective sampling of environmental media, but much of the information required by a preoperational program may already exist in local records. For example, the county courthouse may possess demographic information such as land use plans. Local meteorological conditions may be routinely monitored and recorded at airports, weather stations, or other locations near the LLWBG. Potential sources of information should be investigated prior to commitment to monitoring projects which may, in effect, simply duplicate that which is readily available. Adequacy and reliability of such data should be addressed, however, before being incorporated into the baseline. Areas to be investigated include all of the following.

4.2.1 Meteorology and Climatology

Long-term meteorological data should be collected for the proposed site. The nearest available meteorology station may provide an acceptable alternative to onsite information concerning wind direction, frequency distribution, and atmospheric stability. This information, combined with source terms generated for the site will later be employed to provide dose estimates.

4.2.2 Hydrology and Geology

The ground water monitoring network is the most important portion of the surveillance program at the LLWBG, as it can provide the major moving force for the contaminants. In order to establish a ground-water monitoring network at a disposal site, the following data must be obtained for an adequate understanding of the geohydrologic regime. The general geology of the site must be known, the lithology of the water bearing rock must be understood, and the stratigraphy and any subsurface structures must be mapped.

From this information, a water table contour map should be constructed, the thickness of the aquifer should be obtained, and parameters such as hydraulic conductivity, transmissivity, porosity, specific retention, and others should be obtained in order to permit prediction of the influence of precipitation and the probable rates of movement of possible contaminants in the aquifer.
Chemistry of ground water and rock, making up the aquifer, should be known before site operation is started. If other sources of possible or existing contaminants exist, they should be known and their chemical impact on the ground water understood.

Surface hydrology data are required where any direct or indirect discharge of radioactive materials to a stream or other body of water may occur. For streams or rivers adjacent to a site, information on flow rate, average travel time, dilution, and sediment loading are pertinent. Seasonal flooding and cyclic flow-rate data for most surface streams are available from USGS sources, as are flow models of tidal waters.

Surface soil, collected and analyzed radiochemically, can provide a cumulative indicator of previous radionuclide deposition from weapons test fallout or other human activities. Similarly, subsurface soil samples can provide a profile of natural radionuclide concentration as a function of soil or horizon depth.

4.2.3 Demography, Land Use, and Recreational Patterns

Demographic factors of interest include the population distribution around the site, the location of the nearest residence, details of land usage, recreational and dietary habits. Census data will provide a large part of the required demographic information in most areas; agricultural land use information, including such factors as predominant crops, dairy herd locations, average yield factors, and irrigation practices can be obtained from state or county agricultural extension agents. The extent of recreational activities such as hunting, animal trapping, and off-road vehicle use on or in the vicinity of the site which might lead to a radiation exposure from the LLWBG should be determined. Dietary preferences of the region should be reviewed and compared to the standard pathway parameters. Demographic information will be incorporated into the dose calculation matrix, as illustrated in Figure 2.3.2.

4.2.4 Local Fauna and Flora

Initially, wildlife and indigenous vegetation are sampled to generate baseline concentrations for radionuclides. Wildlife, primarily small mammals, are sampled even though they may not be in a critical path, because
they may forage over or inhabit the LLWBG and may provide a readily measurable indication of "package failure." However, sampling should be tailored to observed utilization of the site, e.g. seasonal habitation. Vegetation is collected to obtain similar baseline evidence of future intrusion into or exposure of buried waste.

4.2.5 Natural Radioactivity

The use and subsequent disposal of technologically-enhanced naturally-occurring radioactive materials dictates a preoperational monitoring program that carefully details the level of both natural and man-made radionuclides that are found in the vicinity of the site.

Even though instrumentation is available that can readily measure background radiation levels, it is difficult to characterize contributors to the dose rate at a site unless measurements are made over an extended period such as one year or more. It is important that this program begin as soon as possible after site selection, remembering that the accuracy with which background can be estimated in a particular situation determines the limit of detectability for exposure attributable to man-made sources.

4.2.6 Detection Capability

There is a great deal of material available on the analytical techniques used for the radiological analysis of environmental samples. One commonly referred to example is HASL-300. Other sources of information on environmental detection capabilities include: ORP-SID/72-2, Regulatory Guides 4.8 and 4.14, ERDA 77-24, and NCRP-50. Table 4.2-1 lists some detection capabilities for radionuclides observed frequently in environmental samples. The criteria include levels of sensitivity expected for each analysis, and typical sample volumes or weights required. In Section 2 minimum performance criteria were provided in terms of dose. Although not certain for all pathways and all nuclides at other than the reference sites, the detection capabilities shown in Table 4.2-1 at least meet the 5 mrem/year dose criterion proffered by Conti.
TABLE 4.2-1. Typical Detection Capabilities for Selected Environmental Sample Analyses (a,b)

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Water (pCi/L)</th>
<th>Air (pCi/m³)</th>
<th>Flora/Fauna (pCi/kg-wet)</th>
<th>Soil-Sediment (pCi/kg-dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross alpha</td>
<td>0.3 (d)</td>
<td>3 x 10⁻⁴ (d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross beta</td>
<td>2 (e)</td>
<td>3 x 10⁻³ (f)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>¹⁴C</td>
<td>100 (k)</td>
<td>5 x 10⁻³ (g,h)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>⁵⁵Fe</td>
<td>20 (h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>⁶⁰Co</td>
<td>15 (e)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>⁹⁰Sr</td>
<td>0.5 (k)</td>
<td>1 x 10⁻³ (n)</td>
<td>150 (e)</td>
<td></td>
</tr>
<tr>
<td>¹⁰⁶Ru</td>
<td>3 (i)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>¹³³Cs</td>
<td>15 (e)</td>
<td>1 x 10⁻² (e)</td>
<td>130 (e)</td>
<td>150 (e)</td>
</tr>
<tr>
<td>²²⁶Ra</td>
<td>0.2 (j)</td>
<td>1 x 10⁻⁴ (j)</td>
<td>0.005 (j)</td>
<td>200 (j)</td>
</tr>
<tr>
<td>²³⁰Th</td>
<td>0.2 (j)</td>
<td>1 x 10⁻⁴ (j)</td>
<td>0.2 (j)</td>
<td>200 (j)</td>
</tr>
<tr>
<td>U (natural)</td>
<td>0.2 (j)</td>
<td>1 x 10⁻⁴ (j)</td>
<td>0.2 (j)</td>
<td>200 (j)</td>
</tr>
<tr>
<td>²³⁹Pu</td>
<td>1 (k)</td>
<td>1 x 10⁻⁵ (k)</td>
<td>1 (k)</td>
<td></td>
</tr>
</tbody>
</table>

(a) The minimum detection capabilities are practical detection levels, typical of those obtained for routine environmental surveillance. Since levels are characteristic of the analytical procedure and instrumentation used in the analysis process, it is necessary to refer to the information sources noted below. Blanks indicate no data readily available.

(b) The tabulated values are for radioanalytical measurements, but direct radiation cannot be overlooked. Suggested detection sensitivities (above background) for direct β-γ radiation measurements are: β dose rate—1 μR/hr; β-γ (surface contamination)—100 cpm (typically performed with a hand-held GM instrument).

(c) While not included in routine surveillance programs to date, two radionuclides included in the reference waste inventory are ¹²⁹I and ⁶³Ni. They are not listed for lack of suitable references. A required minimum sensitivity of 0.1% of 10 CFR 20 (b) dose limits for uncontrolled areas, would suggest the following values: for ⁶³Ni, 30 pCi/L in water and for ¹²⁹I, 60 pCi/L.

(d) Taken from Table 32, BNL 51031 (15).
(e) Taken from Reg. Guide 4.8, Table 3. (10)
(f) Taken from EURA 77-24, Table 2. (11)
(g) Taken from ORP-SID-72-2, Table 2. (12)
(h) Taken from IAEA Safety Series No. 41, Table II. (6)
(i) Taken from HASL-300, Section D004. (9)
(k) Taken from NCRP 50, Table 5-6. (12)
4.2.7 Establishing the Baseline

The motives for establishing a baseline were provided in Section 4.1 under the title "Objectives, Timing, and Duration of a Preoperational Monitoring Program." The means to achieve these objectives were not. Earlier sections established rationale for the selection of media, location, and frequency for sampling. Little was said, however, on how to utilize this information to assess impact.

Until recently, little guidance was available on techniques for handling environmental data to yield reliable information. More importantly, guidance to interpret the information once obtained seemed lacking. A recent publication, (2) "Upgrading Environmental Radiation Data," a Health Physics Society Committee report, was created to address these needs. Some of the more relevant points are presented here.

Representativity of the data that are collected is a source of concern. This is because the data are to be used as a springboard from which to draw conclusions about aspects of the world one did not or could not sample. In doing so, a goal is set, if not always stated, to characterize the value of some parameter over a period of time to some degree of accuracy from a limited number of data points. The data points are limited, because what is sampled can only be a minute fraction of the total environment.

Normally, what is desired is to establish through selective sampling the "background" level of some contaminant in the environment. New data is later compared to the background to see if it belongs. To make the comparison, some assumptions must be made about the behavior of the contaminant in the environment. The assumptions might, for example, include a steady-state concentration or alternatively a concentration decreasing with time. Whatever the assumptions one is predicting of the behavior of some aspect of the environment, a baseline "model" has been established.

Models can range from the very simple to the complex. A single value model would assume that the value of a parameter would remain constant, \(A+B\) at all times and all places. Data collected later would then be used to provide values of \(A\) and \(B\) to be compared to those established. More complex models
might vary with time and space, to mimic a perceived cycle or distribution in nature. While more complex models can better duplicate the real functions in nature, drawbacks are evident. The more intricate ones can lose their usefulness by requiring data that is too difficult or costly to obtain. In the article, "Statistical Methods for Environmental Radiation Data Interpretation,"(14) the following statement about data baselines appeared:

"Reliability of a baseline depends jointly on the established facts about background concentrations, the details of concept regarding variations in background, and the contrast displayed when data are compared to the baseline. The contrasts can be assessed by statistical methods, but they may be of the most simple kind unless near-background contamination levels are of concern. The contrasts may be enhanced either by reducing the effective variance of the baseline or by transforming the data to a form that is amenable to statistical tests that are more valid or more precisely applicable.

As the facts about background concentrations are learned, concepts about the baseline (as a model) deserve to be refined and the results translated into a more astute distribution of samplers, followed by a more precise interpretation of the data they return. Knowledge and concepts about the movements of contaminants may be revised as new data are obtained on background and contaminants. Proposed revisions to currently used concepts can be encouraged throughout the sampling program and new data used to demonstrate their values. In this way the representativity of future data can be pushed to a high degree."

In conclusion, the data from the preoperational program should be used to develop a baseline model. All assumptions about the model should be made explicit and its limitations understood. Its major requirement is for a suitable number of data points to be provided so that predictions (of dose assessment) can be made with some estimate of their precision and reliability.

4.3 LOCATION AND FREQUENCY

Section 4.2 addressed the criteria used in the selection of media for inclusion in the preoperational program. The criteria emphasized both critical paths and sensitivity of specific media as indicators of contaminant movement. The selection of media is, however, only one step in the development of an environmental monitoring program. The next step should be to determine where samples are taken and how often they are collected.
The criteria adopted for sample collection should allow determination of the number of sampling stations per site as well as the collection and analysis frequency. One method of providing such criteria is formal sampling theory. Although this approach provides greater statistical reliability, the number of locations may, depending on geographical variability, become unsupportable. An alternate technique is to base the preoperational program on the expected operational program which would emphasize detection of abnormal results at locations of greatest interest. This latter approach was employed by Waite et al. (14) to provide a specific number of sample locations per medium per site. Rationale was based on the calculated annual dose to the maximum exposed individual. Table 4.3-1 is taken from their paper "Statistical Methods for Environmental Radiation Data Interpretation" and lists their suggestions. This approach provides less valid statistical data for the region as a whole, but can provide equally valid data for specific locations at a fraction of the cost of the purely statistical approach.

Critical pathway analysis, in conjunction with criteria such as that shown in Table 4.3-1, can provide a minimum number of sampling sites per medium. Similarly, the frequency of sampling and measurement activities of other nuclear facilities can provide a useful basis of comparison for developing site-specific programs. One must be cautious, however, of adopting criteria not germane to LLWBGs. For example, one commonly used criterion for sampling intervals is to not exceed $\sqrt{2}$ times the half life. While this admonishment is valid, most radionuclides of interest at the LLWBG will have long half lives. Sampling frequencies based on even one half-life would probably be unacceptable both from a technical and regulatory standpoint.

Once the number of sampling locations has been chosen, their distribution must be decided. There are several techniques currently available to aid in the siting of sampling stations. Three sources of information are Regulatory Guide 4.8 (10) ORP-SID/72-2 (3) and BNWL-SA-4676 (15).

Adopting the criteria suggested above to the media selected for sampling can provide the basis from which a monitoring program is designed. Typical collection frequencies and sampling locations are noted in the subsections that follow and are summarized below in Section 4.4.
TABLE 4.3-1. Recommended Minimum Number of Environmental Sampling Locations Per Nuclear Site as a Function of Calculated Annual Dose to the Maximum Individual(a,b)

<table>
<thead>
<tr>
<th>Environmental Media(c)</th>
<th>Calculated Annual Dose Level (mrem)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-10</td>
</tr>
<tr>
<td>Air, ambient radiation</td>
<td>10</td>
</tr>
<tr>
<td>Milk, other foodstuffs,</td>
<td>5</td>
</tr>
<tr>
<td>water, fish</td>
<td></td>
</tr>
</tbody>
</table>

(a) D. A. Waite, et al.(14)
(b) These criteria are for a dose based program, but are assumed to be equally applicable for other rationale, such as compliance and public relations. 
At higher dose levels (e.g., 10-100 mrem/yr), increase the number of locations by a factor of 3 for each order of magnitude increase in the dose or factor of 10 for each factor of 100 increase in the dose level.
(c) Other media, such as soil and sediment, which are not part of a direct-dose pathway, are excluded (i.e., not required as part of the environmental program). However, there may be other compelling reasons to include them, in which case soil should be added at the same level as air, sediment at the same level as water.

4.3.1 Atmosphere

Air particulate samples would be collected continuously at locations near the site boundary, such as the entrance gate, where the highest airborne concentrations would be expected during site operations.(2,3) One should also be established at a location predicted to remain representative of background conditions for the site. In general, a suitable location would be at a minimum of a 3 km distance and in the least prevalent wind direction from the site in an area that will be undisturbed by site operations. Meteorological data and site plans should provide this information. In addition, if there are any residences or population centers within 10 km of the site,(11) a continuous air sampler should be placed at or near those structures with the highest predicted airborne radionuclide concentration. At a minimum, the nearest residence and population center should have continuous air samplers. If other structures are located in an area where they could receive greater than 10% of the established dose criteria, continuous air samples should be collected there, also.
Air filters for continuous air sampling should be collected biweekly unless excessive dust loading is observed. Constant-flow samplers are strongly recommended to minimize the effects of dust loading on sample volume.

Analyses should consist of gross beta and alpha counts of each sample with a gamma scan of a quarterly composite. Nuclides of special interest include $^{226}$Ra and daughters, long-lived fission products such as $^{137}$Cs, and other frequently seen man-made radionuclides such as $^{60}$Co.

4.3.2 Direct Radiation

Gamma exposure measurements are most frequently made with passive integrating devices such as thermoluminescent dosimeters (TLDs) or pressurized ionization chambers (PICs).

Measurements are made at the locations selected for air particulate samples. Measuring devices should be placed a uniform distance above the ground, (one meter is normally used), and at least 10 meters from the nearest building. Areas where the soil is abnormally wet should be avoided as they can produce misleading information.

If TLDs are used, they should be collected on a quarterly basis to be compatible with the composite data for airborne particulates generated for the same period. PIC results can be integrated over the same time period to facilitate comparison with air particulate composite data.

4.3.3 Hydrosphere

Samples of ground water should be collected quarterly from wells located hydrologically down gradient and upgradient from the proposed low-level waste area. Their locations will be determined by hydrological analysis of the potential movement of seepage from the area. New wells drilled close to the site for the purpose of obtaining representative samples that may be affected by the waste are preferable to existing wells drilled for other purposes.

In arid environs, a limited number of wells need to be drilled, but of sufficient number to determine the requirements for data. A minimum of three wells will be required around the site to establish the basic ground-water flow.
and subsurface geologic characteristics. When the ground-water gradient has been established, the upgradient well should be sampled as a baseline. What is detected in this well should not be the result of site operation.

In areas where the waste is at a significant distance above the ground water, it appears that monitoring in the vadose zone would be of greater value than in the saturated zone. Therefore, it is recommended that three of the shallow wells to be constructed be placed around the site and one on the site (but on the down gradient side). The on-site well can then be used to monitor any change in the water content in the vadose zone below the site. A neutron probe, a geophysical tool, can be used to collect these data. The three outside wells will have resistivity probes installed and resistance measurements below the waste site, but above the saturated zone, will be taken. A change in the percent of moisture shown by the neutron probe or an increase in resistivity shown by the resistivity equipment would indicate a downward movement of moisture from operations or precipitation on the disposal site. By conducting vadose-zone monitoring at the site, corrective action can be taken before contamination reaches the aquifer.

If existing sampling structures (wells) exist at this type of site, they should be modified or replaced with wells that sample no more than the upper 6 m of the aquifer and about 2 m above the top of the ground-water surface. The shallow wells into the vadose zone should be of the plastic casing type and should have permanent electrodes placed in them.

The humid sites, which normally have a shorter distance to the aquifer than arid sites, present a far more serious potential for contamination of the ground water. Therefore, their ground-water monitoring system must be more sophisticated. Flow directions and other geohydrologic parameters must be established to identify any potential migration of a contaminant in the ground water.

Existing sampling structures at such sites should be modified to sample to the "top of the bedrock" and upward to 2 m above the ground-water surface. This site needs a minimum of three wells to establish the geohydrologic and geologic parameters. The upgradient well will be used for a baseline. Past
experience has shown that a "picket fence" design of monitoring wells give adequate warning of contamination of nearby surface bodies of water, with the number of wells used in the picket fence design ranging from about 2 to 10 and spaced based on data obtained as wells are drilled. Since the geology may vary over short distances, the line of wells will give down gradient coverage.

Analyses should consist of gamma isotopic measurements, $^3\text{H}$, gross alpha and gross beta. A procedure which would monitor the vadose zone to show any downward movement of moisture would provide little useful information at the humid site. Monitoring of the ground water at the humid site would be the recommended procedure.

Samples of surface water should be collected from any offsite water impoundment that may be subject to seepage from the waste. They should also be taken from any offsite surface waters that may be subject to runoff or drainage from potentially contaminated areas. Any stream beds onsite that are dry part of the year should be sampled when water is flowing. Samples should also be collected at a control site and at or as near as possible to the site boundary.

Analyses will be the same as for ground water: gamma scan, gross alpha, gross beta, and $^3\text{H}$.

Drinking water (well or surface water) should also be collected from each source that is or could be used for drinking water, watering of livestock, or crop irrigation within 2 km of the site. Control locations will be the same as those for surface or well water.

Analyses will be the same as for ground water.

4.3.4 Geosphere

Prior to trench construction, three types of soil samples should be collected. The first is a surface soil sample, and the recommended technique used for its collection is from HASL-300. No single soil sampling method, however, is adequate for all locations due to the variability in soil compositions. For the arid region, where soils may be dry and loose, the soil sample may not adhere to the sample cutter on removal. An alternate method applicable
to the arid site is discussed in PNL-MA-580. This method involves clearing away the soil adjacent to the sample cutter prior to removal from the ground and then sliding a trowel under the cutter to prevent the soil from escaping. Samples to a depth of 5 cm should be obtained.

The second type of soil sample to be collected is a depth profile and is described in Regulatory Guide 4.5. The third sample is an extension of the depth profile and uses a soil core to examine strata to a depth of 2 m below trench level for natural radioactivity with portions of soil being analyzed at each soil horizon.

Analyses of soil should include some in situ gamma isotopic measurements.

One set of sediment samples should be collected from the surface-water locations adjacent to the site, and should be sampled upstream and downstream of the site. Samples should be collected following spring runoff and in later summer, preferably following an extended period of low flow. In each location, several sediment samples should be collected in a traverse across the body of water and composited for analysis. Analysis is the same as for soil above.

4.3.5 Biosphere

This category would include small mammal sampling. Small mammals such as mice, rabbits, muskrats, and ground squirrels should be trapped onsite. Wildlife that is relatively rare locally should not be taken for samples routinely, nor of course any threatened species.

Game birds, if hunted locally in the neighborhood of the site, should be sampled during the hunting season on and around the site vicinity.

Analyses should include gamma scans on the edible portions. If small mammals such as mice are sampled, the entire animal should be submitted to analyses.

Vegetation should be collected in the vicinity of each soil sampling location and from areas which may later be contaminated by migrating waste.
Samples should be cut from the green growing ends of perennial vegetation. Exposed surfaces of the vegetation can provide evidence of deposition of pollutants and, therefore, should not be washed before analysis.

Analyses should consist of gamma scans.

4.4 PREOPERATIONAL PROGRAM SUMMARY

Two preoperational surveillance programs were designed for the reference sites using the rationale presented in this Section and previously. Table 4.4-1 illustrates the programs as they would be recommended to the site operator. Summarizing the reasons behind the number of locations and collection frequencies shown:

- **Atmosphere**: Air particulates are expected to be a primary source of atmospheric contamination from the LLWBGs. The major impact is predicted to be during the operational, site-closure, and decommissioning stage of both sites. However, because airborne material is not expected to provide the dominant mode of exposure only 3 sites are established. If later dose calculations indicate a greater contribution, the number of sampling stations would be increased accordingly as per Table 4.3-1.

- **Direct**: Direct radiation, particularly during the normal operation of the LLWBG and at waste exhumation, presents the greatest potential for exposure, hence 10 sites are selected.

- **Hydrosphere**: Ground-water monitoring while of importance is not expected to show the same variability as atmospheric or direct pathways. A smaller number of sampling sites can therefore be used, as "background" data will be collected over a long period of time.

- **Surface and Drinking Water**: With the exception of accidents, surface and drinking water would show evidence of contamination only after it was observed in the ground water near the site.
**TABLE 4.4-1. Preoperational Environmental Surveillance Programs for the Reference Low-Level Waste Burial Grounds**

<table>
<thead>
<tr>
<th>Medium</th>
<th>Sample</th>
<th>Number and Frequency of Collection</th>
<th>Arid Site</th>
<th>Humid Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>Particulate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Onsite(a)</td>
<td>1--Biweekly</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Offsite(b)</td>
<td>3--Biweekly</td>
<td>1--Biweekly</td>
<td>3--Biweekly</td>
</tr>
<tr>
<td>Direct</td>
<td>Dosimeters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>7--Quarterly</td>
<td></td>
<td>7--Quarterly</td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td>3--Quarterly</td>
<td>3--Quarterly</td>
<td>3--Quarterly</td>
</tr>
<tr>
<td>Hydrosphere</td>
<td>Ground Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>3--Quarterly</td>
<td>3--Quarterly</td>
<td>3--Quarterly(c)</td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td>2--Quarterly</td>
<td>2--Quarterly</td>
<td>3--Quarterly</td>
</tr>
<tr>
<td>Geosphere</td>
<td>Soil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>3--Quarterly</td>
<td>3--Quarterly</td>
<td>3--Quarterly(d)</td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td>2--Quarterly</td>
<td>2--Quarterly</td>
<td>2--Quarterly</td>
</tr>
<tr>
<td></td>
<td>Sediment</td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td></td>
<td>2--Quarterly</td>
<td>2--Quarterly</td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td></td>
<td>2--Quarterly</td>
<td>2--Quarterly</td>
</tr>
<tr>
<td>Biosphere</td>
<td>Small Mammals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>3--Quarterly</td>
<td>3--Quarterly</td>
<td>3--Quarterly</td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td>2--Quarterly</td>
<td>2--Quarterly</td>
<td>2--Quarterly</td>
</tr>
<tr>
<td></td>
<td>Game Birds</td>
<td></td>
<td>3--In Season</td>
<td>3--In Season</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>3--In Season</td>
<td>3--In Season</td>
<td>3--In Season</td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td>2--In Season</td>
<td>2--In Season</td>
<td>2--In Season</td>
</tr>
<tr>
<td></td>
<td>Vegetation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>3--Quarterly</td>
<td>3--Quarterly</td>
<td>3--Quarterly</td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td>2--Quarterly</td>
<td>2--Quarterly</td>
<td>2--Quarterly</td>
</tr>
</tbody>
</table>

(a) Onsite sampling locations include the site boundary.
(b) Offsite includes control, nearest residence, and nearest population center.
(c) The two offsite wells form the minimum basis for the "picket fence" line of wells to provide down gradient information.
(d) In addition to surface samples, a one-time set of depth profile and core samples should be taken.
• **Geosphere:** Contaminated soil and sediment are not considered to be major contributors to the direct dose pathways predicted for the LLWBG, but are included primarily because they indicate the movement of contaminants through the environment.

• **Biosphere:** Experience has shown that intrusion by burrowing animals does occur at LLWBGs. While they may not be in a critical pathway to man (except perhaps rabbits) the likelihood of their intrusion is a compelling reason to sample.

  Game birds similarly present a problem, but they are in the direct-dose path, unlike small mammals. They are sampled commensurate with their anticipated contribution to dose.

  Vegetation is sampled for two different reasons. It is expected to provide evidence of root intrusion into the wastes and to indicate surface contamination from deposition of airborne particulates.

### 4.5 REFERENCES


*Available for purchase from the NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, DC 20555, and/or the National Technical Information Service, Springfield, VA 22161.

**Single copies are available free upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.
5.0 OPERATIONAL ENVIRONMENTAL SURVEILLANCE

The principles discussed in Section 4 can be applied to the two reference sites during their operational phases to demonstrate the applicability and use of this rationale.

5.1 OBJECTIVES OF OPERATIONAL ENVIRONMENTAL SURVEILLANCE PROGRAMS

While the general objectives of environmental surveillance stated in Section 2 apply, the results of the operational monitoring program are more specifically intended to verify that the measured concentrations of radionuclides or other pollutants are not higher than expected on the basis of the known exposure pathways.

The operational monitoring program should therefore concentrate on providing measurements of radiation and radioactivity concentrations along exposure pathways which are predicted to lead to the highest potential exposure of individuals from operation of the LLWBG. The operational monitoring program should begin just prior to receipt of waste and include those media indicated by preoperational surveillance as key indicators of contaminant movement. Some other preoperational measurements will be continued to demonstrate continuing control and to detect any changes from previous experience.

5.2 MEDIA AND MEASUREMENTS

As discussed in earlier sections, critical pathway analysis provides the basis for operational monitoring programs at LLWBGs. The operational monitoring programs will continue those developed during the preoperational phase with modifications where appropriate.

Fewer media are expected to be sampled in the operational phase of the surveillance program than in the preoperational phase, since multiple measurements in a single exposure pathway should not be necessary. Further evaluation of pathways during the preoperational program may indicate lesser importance than originally expected.
Radiological exposure pathways for the two reference sites addressed here and considered most important during the operational stage are: inhalation of air particulates containing radionuclides (both sites), and direct external exposure from waste handling operations or surface contamination (both sites).

5.3 LOCATION AND FREQUENCY

The programs recommended for the two reference sites include surveillance of the following exposure pathways: ground water, direct radiation, air, biota, and soil sampling. As discussed in Section 4.2, not all pathways investigated during the preoperational phase will have proved to be critical or predominant ones. Therefore, many of them will not be sampled during the routine operational environmental surveillance. Uniformity of results may permit some reduction of sample location or collection frequency, but any reductions will require documentation that the change will not adversely affect the detection capability of the program.

5.3.1 Meteorology and Climatology

Critical pathway predictions indicate that for the two reference sites atmospheric releases are not anticipated to provide a major source of exposure\(^{(2,3)}\) under "normal" operating conditions. Experience has shown, however, that abnormal occurrences may result in resuspension of contaminated soil. Therefore, the number of air particulate samplers should be left at its pre-operational level.

With wind patterns adequately documented, it becomes possible to position air samplers in areas of predicted maximum airborne concentrations.

5.3.2 Direct

Particularly during waste unloading operations, direct radiation presents a potential for exposure. The number and frequency of measurements remains unchanged.
5.3.3 **Ground Water**

Test wells continue to be sampled to determine the impact of waste disposal on the regional ground-water quality and to monitor for migration of waste. Wells are sampled with a frequency based both on their location within the ground-water flow network and the concentrations of radionuclides observed in the samples.

If in fact a contaminant does reach an aquifer, the expected behavior of the contaminant plume must be considered in establishing an effective surveillance program. The center of a plume will show the highest concentration, since, dilution and dispersion will be highest along the outside edge of the plume. Contaminants will generally be near the top of the aquifer if they are migrating downward from a source. Generally when diffusion is occurring, the contaminant will move at or faster than the ground-water flow rate, although the difference may be negligible or even reversed at some distance from the point of entry to the aquifer if soil adsorption occurs. This can result in a rapid horizontal movement of the contaminants.

The pathways of contaminants will always be perpendicular to the water level contours of an aquifer because they will be following the ground-water flow lines. Therefore, artificial stresses on the aquifer, such as a pumping well, will result in contaminants moving in the direction toward that well. The movement of the various contaminants within a plume will have a direct relationship to the attenuation in the geologic media, as expressed by distribution coefficients, \( K_d \). Selected coefficients were given in Table 3.3-1 of Section 3.

5.3.4 **Soil**

Soil samples are analyzed for radionuclide contamination resulting from airborne deposition or ground-water migration. This medium is not predicted to be a significant part of a critical path for either site (air particulate is presumed to have greater impact), and so the sampling frequency may be reduced from preoperational levels. These samples can, however, provide an indication of trends in radionuclide buildup.

5-3
Samples taken during routine operations will be collected primarily from the surface since deposition is the dominant mode at this early stage. If migration of waste is observed through test wells then soil profiles would be appropriate to help document the extent of the migration.

5.3.5 *Local Fauna and Flora*

Small mammals continue to be routinely collected in the site environs. Animals are selected based on their observed contact with the site, and at the time of year corresponding to their maximum utilization of it.\(^1,3\) Small animals are sampled not only because they are most likely to intrude directly into the waste site, but also because they may feed on contaminated vegetation. Evidence of such activities should manifest itself in elevated levels of internal or external radioactivity.

Game animals, including fowl, should continue to be sampled with the same frequency established for the preoperational phase.

Vegetation samples continue to be collected but at longer intervals. They may indicate current concentrations in an exposure pathway to man, and can be used to indicate the accumulation of contamination in a locality.\(^1,3\) Accumulation is assumed to occur through root uptake of contaminated ground water or soil, or through deposition directly onto the surface of the vegetation. Routine annual off-site sampling should consist of a representative composite of the green growing ends of perennial vegetation; the same or related species should be collected at each sample location. This is done to allow comparison of contamination levels from location to location and to show any trends at each location over several years.

In conclusion, sample stations may be the same as those used in the preoperational program, but should periodically be reevaluated for adequacy of location. Some onsite sampling locations will change. Air samples, for example, should be taken in locations downwind of current trenching and burial operations. Soil samples may be collected from air sampler locations as well as over capped trenches.
Collection frequency and specific analyses for the routine operational environmental surveillance programs are site specific. The programs should be reassessed every few years to determine if modification is warranted. Such evaluations should be based on:

- changes in the quantity or characteristics of the wastes compared to information on which the program was designed,
- information supplied by the existing program which indicates that portions of the program may be dropped with no loss in effectiveness,
- information that indicates media not currently sampled have the potential for exposure or buildup of contaminants,
- new legislation dictating changes in monitoring requirements, and
- shifts in population distributions or land usage around the site.

Routine operational surveillance programs for the reference sites are shown in Table 5.3-1. The number of sampling sites for each medium is based on the criteria discussed in Section 4.3 and the critical paths predicted in Table 3.4-1.

The analyses of samples can be reduced to save on time and costs. Specific nuclides can be preferentially monitored in the media where they are most likely to first appear, such as described for ground-water monitoring in Section 4.3. Action levels using differing degrees of analyses could be established. For example, if routine scans of samples detect concentrations that are greater than two standard deviations from the calculated background mean, then further investigation is warranted. The investigation would entail a more detailed analysis, but not necessarily any corrective action. The reason is that, on the average, 2-1/2% of all samples analyzed would fall outside this value. However, if a sample was found that exceeded four times the standard deviation, the chance that it would be a normal member of the population is small; about 1 in 31,000. In such cases immediate action should be taken to determine the extent of the contamination and take appropriate control measures. Results of this kind may require reporting even if no action is indicated.
<table>
<thead>
<tr>
<th>Medium</th>
<th>Sample</th>
<th>Number and Frequency of Collection(a)</th>
<th>Arid Site</th>
<th>Humid Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>Particulate</td>
<td>1--Biweekly</td>
<td>1--Biweekly</td>
<td>1--Biweekly</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>3--Biweekly</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Offsite(b)</td>
<td></td>
<td>3--Biweekly</td>
<td></td>
</tr>
<tr>
<td>Direct</td>
<td>Dosimeters</td>
<td>7--Quarterly</td>
<td>7--Quarterly</td>
<td>7--Quarterly</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>3--Quarterly</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Offsite(b)</td>
<td>3--Quarterly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrosphere</td>
<td>Ground Water</td>
<td>3--Semiannually</td>
<td>3--Quarterly</td>
<td>3--Quarterly</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>2--Semiannually</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
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<td>2--Semiannually</td>
<td></td>
<td></td>
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<td>2--Semiannually</td>
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<td>Offsite</td>
<td>1--Semiannually</td>
<td>1--Semiannually</td>
<td></td>
</tr>
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<td>Geosphere</td>
<td>Soil</td>
<td>2--Annually</td>
<td>2--Annually</td>
<td></td>
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<tr>
<td></td>
<td>Onsite</td>
<td>1--Annually</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Offsite</td>
<td></td>
<td>1--Annually</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sediment</td>
<td>N/A</td>
<td>2--Annually</td>
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<td>Onsite</td>
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<td>N/A</td>
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<td>Offsite</td>
<td>2--Annually</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td></td>
<td>2--Semiannually</td>
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</tr>
<tr>
<td>Biosphere</td>
<td>Small Mammals</td>
<td>3--Annually</td>
<td>3--Annually</td>
<td></td>
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<tr>
<td></td>
<td>Onsite</td>
<td>2--Annually</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Offsite</td>
<td>2--Annually</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Game Birds</td>
<td></td>
<td>3--In Season</td>
<td>3--In Season</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>2--In Season</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Offsite</td>
<td></td>
<td>2--In Season</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vegetation</td>
<td>3--Annually</td>
<td>3--Annually</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>2--Annually</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td></td>
<td>2--Annually</td>
<td></td>
</tr>
</tbody>
</table>

(a) See Section 4.3 for specific analyses.
(b) Includes control, nearest residence, and nearest population center.
The reference radionuclide inventory for the two sites was used to develop a tiered analysis scheme for operational environmental surveillance. Based on the concentrations of radionuclides found at the waste site, their concentration guides (from 10CFR20, Appendix B, Table II), and their predicted mobilities in soil and ground water, it was possible to rank the analyses. Table 5.3-2 suggests such a multi-level analysis scheme using radionuclides that would be the most important for the reference sites. The suggested analyses in this table are grouped according to relative environmental mobility and predicted radiological significance if radionuclide migration occurs from the reference LLWBGs. The first group—\(^{3}\)H, alpha, and beta—includes those analyses (and pathways) predicted to be the most important in determining movement of radioactivity from an LLWBG site. The second and third groupings include analyses which should be considered in particular media based on the levels of contaminants observed. The analyses shown are illustrative and not necessarily all inclusive.
<table>
<thead>
<tr>
<th>Nuclides or Analysis</th>
<th>Water</th>
<th>Flora/Fauna</th>
<th>Soil/Sediment</th>
<th>Air</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group I</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^3$H</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross Alpha</td>
<td>X(a)</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Gross Beta</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Group II</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamma Scan</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>($^{106}$Ru, $^{137}$Cs)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>$^{226}$Ra</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Group III</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{55}$Fe</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>$^{63}$Ni</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>$^{90}$Sr</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>$^{239}$Pu</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>$^{241}$Am</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

(a) For saline or water samples with a high organic content, a gamma scan is suggested since the presence of naturally occurring $^{40}$K may mask the contribution of beta-emitting contaminants.
5.4 REFERENCES


6.0 POST-OPERATIONAL ENVIRONMENTAL SURVEILLANCE

Site closure and stabilization are intended to prepare the site for transfer to a custodial government agency. The custodial agency or agencies will need to perform the environmental surveillance discussed in this section until the site can be released for unrestricted use, either through radioactive decay or exhumation of residual radioactivity. The site operator's responsibility and authority for possession of buried wastes continues until the NRC finds that the plan established for preparation of the site for transfer to another entity has been satisfactorily completed. LLWBG licensees for the reference sites are assumed to have developed a site closure and stabilization plan that meets the minimum performance objectives.

The environmental surveillance program during the post-operational period may be somewhat different for the arid and humid sites, even though the critical pathways may be much the same, since the chain of events leading to human exposure may differ for the two sites. In addition, the critical pathways are expected to change during the course of this post-operational period. This phase includes the site/waste stabilization which immediately follow cessation of waste receipt, short- and long-term custodial care, but does not include decommissioning operations. Critical paths will certainly be different for site closure operations than for short- and long-term care.

6.1 OBJECTIVES OF POST-OPERATIONAL PROGRAM

The primary intent of environmental surveillance after site closure is to ensure that stabilization activities do not cause significant transport of radioactivity from the site, resulting in an unacceptable health hazard to the public. During short- and long-term care, environmental surveillance serves to verify the continuing radionuclide confinement capability of the burial ground and to identify problem situations requiring remedial action.

6.1.1 Impact of Site/Waste Stabilization

Stabilization operations will require a somewhat modified surveillance program than was called for in the operating license, primarily for added
airborne particulates and soil sampling and reduced direct radiation measurements. These additions will serve to identify potential movement of radionuclides due to the significant disturbance of soils.

6.1.2 Short-Term Care

Administrative control of LLWBGs during the initial three years following site closure are expected to remain with the site operator. Generally this period will be necessary to establish appropriate long-term maintenance and surveillance requirements for the site and to prepare for license transfer. Specific requirements at this time include summarization and interpretation of available environmental surveillance and inventory data generated during operation and site stabilization. Baseline data for future comparison during long-term care will also need to be generated. The primary objective continues to be demonstrating compliance of environmental contaminant levels with the then current regulations (Federal or State).

6.1.3 Long-Term Care

Long-term care of a LLWBG site includes all procedures required to verify site capability to confine the radionuclides to the immediate vicinity of the burial trenches. These procedures are, in general, a continuation of surveillance procedures established during site operation and stabilization. Long-term surveillance of a site continues until it is determined that the buried waste materials no longer pose a potential radiological hazard, which may require removal of residual radioactivity, and the site is finally decommissioned and released for unrestricted public use.

The objectives of environmental surveillance during this final phase are to assure continued radioactive waste confinement within the site, to identify problems requiring remedial action, and to compare residual environmental conditions with potentially changing regulations. Evaluation of environmental surveillance data should be performed periodically (annually, or more often if indicated by abnormal conditions) to verify the adequacy of site maintenance activities and to detect any unusual radionuclide migration. To insure availability of environmental data for continuing evaluation, it is important to store the data in a form that permits ready retrievability.
6.2 MEDIA AND MEASUREMENTS

Critical pathways determination suggests media and possible nuclides to evaluate in designing the site-specific environmental surveillance program. Radionuclide migration or release routes of importance for the reference sites are listed in Table 3.4-1 based on their nuclide inventory and critical exposure pathway estimates. The dominant release mechanisms for the reference western site in chronological order during the post-operational phase are:

- human activities (excavation)--site/waste stabilization
- wind erosion--long-term care
- deliberate intrusion--long-term care
- hydrological releases--long-term care

For the reference eastern site, the dominant potential release mechanisms for the post-operational phase are:

- human activities (excavation)--site waste stabilization
- hydrological releases (percolation and overflow)--long-term care
- water erosion--long-term care

6.2.1 Site/Waste Stabilization

Stabilization of a burial ground site involves movement of surface soils for improved contouring and drainage control, but no intentional uncovering or exhumation of buried wastes. Therefore, the environmental monitoring program during stabilization is postulated to be reduced from that during burial operations, except that:

- Onsite soil sampling is expected to increase to detect any changes in soil radioactivity resulting from soil disruption during stabilization activities.
- If stabilization activities result in an increased dust loading in the air, additional air samples may be required.
- Additional onsite radiation survey measurements, with a GM or similar portable instrument, are suggested as a "quick-sort" for determining any surface areas that may require further soil moving/analysis.
• Sampling of onsite vegetation is expected to continue during stabilization as another indicator of possible radionuclide contamination from the LLWBG.

6.2.2 Short-Term Care

Following site stabilization, it should be possible to reduce the level of environmental monitoring from that required during site operation. However, some environmental sampling and analyses will be needed for a few years (maximum of three years) to evaluate the effectiveness of site stabilization. No further earth moving or waste burial activities are planned or expected to be conducted on the site. Hence, the only environmental pathways of potential concern at the arid site are ground water, onsite vegetation, and burrowing animals, while for the humid site, storm runoff and local surface waters may also be of concern. As discussed in the previous sections, the critical potential routes of contaminants to man should continue to be sampled and analyzed for specific nuclides. However, it is recognized that analyses here may be somewhat different than during earlier phases of surveillance, based on the experience gained. If no contaminants have been detected beyond the individual trench boundaries, only those contaminants providing a first indication of movement may need to be included in the analyses. Such analyses should include $^3$H in water samples, and the relatively abundant $^{60}$Co and $^{137}$Cs in flora and fauna samples.

6.2.3 Long-Term Care

Barring unexpected events, such as floods, animal burrowing, or human intrusion, the level of environmental surveillance required during long-term care should be much reduced. An annual visual inspection of the site should be scheduled for evidence of intrusion, subsidence of backfilled areas, and general site appearance. At the same time as this inspection, the annual sampling of ground water and other media may be done as described in Table 6.3-3 (included at the end of Section 6). It is recommended that these annual inspection and sampling programs be continued for another 30 years beyond the projected operating life-time of the LLWBG. This continuation of sampling and analyses is in harmony with the recommended continuation of
ground-water monitoring at hazardous waste disposal sites of 20 years\(^1\) and NRC's maximum licensing period of 40 years.\(^2\) Thirty years should allow sufficient time to detect years should allow sufficient time to detect very slow ground-water transport of contaminants (if occurring) and to permit deep-rooted vegetation to become reestablished after active site disturbance (following site closure). If a site is decommissioned or radioactive decay of the residual inventory eliminates the risk of translocation of radioactivity, then continued visual surveillance, direct radiation surveys, and ground water monitoring would be discontinued at that time.

6.3 MEASUREMENTS: LOCATION AND FREQUENCY

Environmental monitoring suggested for the post-operational phase of the reference low-level waste burial grounds are similar to those during burial operations. These include sampling of water, soil, vegetation and air, and direct radiation measurements to assure that adequate confinement at the LLWRG is maintained. Specific monitoring programs for each generic site are given in Tables 6.3-1, 6.3-2, and 6.3-3 corresponding to site/waste stabilization, short-term care, and long-term care.

Since the most probable mode of radioactivity movement from the reference LLWRGs is through the hydrogeologic cycle, the best indication of this migration is through measurement of tritium (which follows the water-cycle) in ground water. In addition, other nuclides whose mobility in soils is potentially large include \(^{14}\)C, \(^{60}\)Co, and \(^{106}\)Ru. These nuclides may be determined through separate analyses, while the movement of most other nuclides can be traced by gross and analyses. Gamma spectral analyses are suggested to identify specific radionuclides in other media or in samples which indicate gross activity levels greater than preoperational or control location levels, as shown in Table 5.3-2.

6.3.1 Environmental Surveillance for Site Stabilization

6.3.1.1 Atmosphere

For both sites, six continuous air sampling stations are suggested. The onsite samples should be collected at the site perimeter in the most probable
downwind directions from earth-moving activities. The offsite samplers
should be placed at the nearest residence and population centers downwind of
the site. The other should be positioned 1.6 km or more in the most probable
upwind octant to serve as a control sample. Ideally the control location will
be the same one used during the preoperational and operational phases. Parti-
culate filters are suggested for all locations. These samples should be
changed weekly. The particulate filters should be weighed for total particu-
late loading, and counted for total alpha and gross beta radioactivity. Mea-
sured activity greater than two times the standard deviation of the control
sample may require additional specific isotopic analysis.

### TABLE 6.3-1. Post-Operational Environmental Surveillance Programs for the
Reference LLWBGs--Site/Waste Stabilization\(^{(a)}\)

<table>
<thead>
<tr>
<th>Medium</th>
<th>Sample</th>
<th>Number and Frequency of Collection(^{(a)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmosphere</td>
<td>Particulate</td>
<td>Arid Site</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>3--Weekly</td>
</tr>
<tr>
<td></td>
<td>Offsite(^{(b)})</td>
<td>3--Weekly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humid Site</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3--Weekly</td>
</tr>
<tr>
<td>Direct</td>
<td>Dosimeters</td>
<td>Arid Site</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>3--Quarterly</td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td>1--Quarterly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humid Site</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3--Quarterly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1--Quarterly</td>
</tr>
<tr>
<td>Geosphere</td>
<td>Soil</td>
<td>Arid Site</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>3--Weekly(^{(c)})</td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td>1--Annually</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humid Site</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3--Weekly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1--Annually</td>
</tr>
<tr>
<td>Biosphere</td>
<td>Small Mammals</td>
<td>Arid Site</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>5--(if available)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Humid Site</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5--(if available)</td>
</tr>
</tbody>
</table>

\(^{(a)}\) Only those program elements that differ from the operational phase
are shown here since site/waste stabilization is expected to involve
less than one year. (All other routine sampling will continue at
the frequencies shown in the operational program, Table 5.3-1; see
Section 4.3 for specific analyses and discussion of sampling
techniques).

\(^{(b)}\) Includes one control sample location.

\(^{(c)}\) Frequency should be dictated by activities (actual soil disturb-
ance); monthly or quarterly may be adequate in conjunction with the
onsite health physics program.
### TABLE 6.3-2. Post-Operational Environmental Surveillance Programs for the Reference LLWBGs--Short-Term Care

<table>
<thead>
<tr>
<th>Medium</th>
<th>Sample</th>
<th>Number and Frequency of Collection(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrosphere</td>
<td>Ground Water</td>
<td>Arid Site</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>Semiannually</td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td>Quarterly</td>
</tr>
<tr>
<td></td>
<td>Surface Water</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Offsite</td>
<td>Semiannually</td>
</tr>
<tr>
<td></td>
<td>Drinking Water</td>
<td>Semiannually</td>
</tr>
<tr>
<td>Biosphere</td>
<td>Small Mammals</td>
<td>Semiannually</td>
</tr>
<tr>
<td></td>
<td>Onsite</td>
<td>Annualy</td>
</tr>
<tr>
<td></td>
<td>Vegetation</td>
<td>Annualy</td>
</tr>
</tbody>
</table>

(a) See Table 4.2-1 for typical analytical sensitivities and dose criteria in Table 2.4-1.
(b) Samples as indicated in addition to GM meter reading at 50 meter intervals over waste trenches.

### TABLE 6.3-3. Post-Operational Environmental Surveillance Program for the Reference LLWBGs--Long-Term Care

<table>
<thead>
<tr>
<th>Medium</th>
<th>Number of Measurements</th>
<th>Analyses (Annually)(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Water (onsite and offsite)</td>
<td>6</td>
<td>3H</td>
</tr>
<tr>
<td>Vegetation (onsite)</td>
<td>12</td>
<td>Gamma Scan</td>
</tr>
<tr>
<td>Small Mammals (trapped onsite)</td>
<td>4</td>
<td>Gamma Scan</td>
</tr>
<tr>
<td>Direct Radiation (onsite vegetation)</td>
<td>50 meter grid</td>
<td>Count rate (GM)</td>
</tr>
</tbody>
</table>

(a) If activity is detected above the action levels suggested in Section 5, Table 5.3-2, additional sampling and analyses as may be indicated is recommended.
6.3.1.2 Direct Radiation

Measurements of external radiation during site stabilization will be decreased in this portion of the post-operational program since the impact of site stabilization activities should be to add shielding rather than to uncover the already buried wastes.

6.3.1.3 Ground Water

Sampling and analysis of ground water from all remaining accessible well sampling points, both onsite and offsite, should be continued, at the operational monitoring frequency. Tritium analyses on these samples are suggested since it is the most mobile and likely contaminant in ground water. Other analyses might include nitrate ion (NO$_3$) total dissolved solids and total organic carbon, a useful addition for onsite samples as an indicator of trench leaching, at least at the arid site. At least one onsite well sampling point must remain to provide continued leach detection.

6.3.1.4 Soil and Vegetation

Existing operational requirements for soil and vegetation sampling will be continued, but with soil sampling to follow completion of the earth moving activities, rather than on a regular basis. Soil samples are to include analysis only for total alpha, gross beta, and gamma radioactivity. Any sample result greater than two times the standard deviation of the most recent previous results for the same medium and location will be cause for the follow-up actions specified in previous sections. Vegetation samples will be analyzed for gamma radioactivity.

6.3.1.5 Other Biota and Foods

No increased sampling is required during site-stabilization operations at the reference sites.

6.3.2 Environmental Surveillance for Short-Term Care

The proposed environmental surveillance program for the short-term care period is shown in Table 6.3-2. During this transitional period, the groundwater sampling continues much as before to sample for movement of radioactivity previously leached from the most recently buried wastes. Vegetation sampling
in a random pattern over the now-covered trenches is increased to permit some statistical inferences to be drawn from cumulative results.

6.3.3 Environmental Surveillance for Long-Term Care

Ground-water samples are taken from the same wells used during the short-term care period. Measurements are made on an annual basis only unless site inspections indicate a shorter frequency is warranted. Vegetation samples continue to be taken in a random pattern over the site.

Direct radiation measurements are made with a Geiger-Mueller probe (or some other similarly sensitive radiation detection device). The purpose is not to obtain dose rates but to monitor for evidence of contamination and/or loss of shielding. A count rate at any location equal to or greater than two times the background count rate would call for additional soil and vegetation sampling to verify the presence of surface contamination and define the need for remedial action (if warranted).

6.5 REFERENCES


7.0 ENVIRONMENTAL SURVEILLANCE FOR THE DECOMMISSIONING PHASE

This section deals primarily with surveillance and maintenance of the site as it relates to waste relocation. Primary concerns during this period are to assure public safety and safety of the staff maintaining the site. The site may still contain amounts of special nuclear and/or other radioactive material that require safeguards or other regulatory control. For this period, the license may need to be amended consistent with the stored (contained) inventory of special nuclear material and the level of potential public safety concern the facility represents. Following waste relocation, termination of the facility license(1) and release of the site could then occur.

Before decommissioning begins, an environmental impact statement may be required, under the National Environmental Policy Act, describing the probable effects of the proposed decommissioning actions. A preliminary appraisal will be needed for license amendment or termination in any case. It is assumed that a formal environmental impact statement would not be required for site stabilization and long-term care, but might be required if extensive exhumation is planned. These actions themselves will include a discussion of the then current environmental surveillance program at the specific site. From this and the proposed decommissioning activities, one can then suggest modifications to the existing environmental monitoring program.

Several states have enacted NEPA-type legislation which may require a formal impact statement if the facility is state-licensed. If a formal environmental statement is not required, a negative declaration(a) and an environmental assessment may still be necessary. Guidance is provided on the need for the content of an assessment by the Council on Environmental Quality.

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(a) A negative declaration is a document prepared by the NRC that states that the NRC has decided not to prepare an environmental impact statement for a particular action, and that an environmental assessment setting forth the basis for that determination is available for public record.
7.1 **SCOPE OF ENVIRONMENTAL SURVEILLANCE FOR DECOMMISSIONING PHASE**

If the decommissioning of a low-level burial ground will entail the removal of residual radioactive materials, detailed procedures for the disposition of these wastes must be clearly defined in the license amendment application. The decommissioning option considered in this addendum is waste relocation, and considerations for it have been factored into the environmental surveillance needs. Preliminary guidance on monitoring specifically for compliance with decommissioning criteria is provided in a recent Oak Ridge progress report. Once a decommissioning mode has been selected and the license has been amended, the actual decommissioning activities can be initiated concurrent with appropriate changes to the environmental surveillance program.

7.2 **ENVIRONMENTAL SURVEILLANCE FOR WASTE RELOCATION**

Waste relocation activities, as part of the decommissioning phase, may result in significant changes to the environmental surveillance program, compared to those in the post-operational phase (Section 6). The objectives are to verify continued confinement of the buried radioactivity and provide a surveillance program that permits this evaluation. Because this phase involves "unknowns," close health physics supervision as well as the "backup" provided by environmental surveillance are expected to be increased during any exhumation operation.

The environmental media sampled during waste relocation are postulated to be similar to those during burial operations, and no specific program is outlined for this monitoring phase. Special samples or analyses may be required by the regulatory agency responsible for the site or by the health and safety supervisor. Specific monitoring program emphases during waste relocation include:

- Collection and analysis of water in trenches uncovered as part of the waste relocation process.
Onsite soil samples to assure exhumation activities have not contaminated surface soils. These samples are expected to be taken in areas of greatest soil disruption, according to specifications prepared during planning and preparation for decommissioning.

Air particulate samples will be required, primarily because soil disturbance activities may create increased dust loading in the air. Additional samplers are suggested offsite in the prevailing downwind direction. A constant air monitor may also be used onsite as part of the monitoring program near the work area to detect sudden changes in airborne radioactivity.

Sampling of vegetation is suggested but because disruption of onsite vegetation is inevitable during waste relocation, special sample points may be required.

Some sampling of burrowing animals or other fauna observed during the "retrenching" may be advisable based on specific situations and desire to interpret potential nuclide movements from the trench.

7.2.1 Atmosphere

For both reference sites, six continuous air sampling stations are suggested. The onsite samplers should be placed at the site perimeter in the most probable downwind directions from earth-moving activities, but moved as required based on these activities. The offsite samplers should be positioned as follows: one 1.6 km or more in the most probable upwind octant to serve as a control sample, and the other two at the nearest residence and population center downwind of the site. Ideally, the control location will be the same one used during the operational and post-operational periods. Particulate filters are suggested for all locations, changed weekly or as dust loading requires. The particulate filters should be weighed for total particulate loading, and counted for total alpha and gross beta radioactivity. Measured activity greater than two times the standard deviation of the control sample should prompt specific isotopic analysis.
7.2.2 Direct Radiation

Measurements of external radiation should include at least all of the air sampling locations. Up to ten additional locations are suggested along the same down-wind site perimeter as well as in the downwind third of the adjacent perimeter boundaries. TLDs are suggested because of simplicity in measurement. A monthly change frequency or at the conclusion of waste relocation activities, whichever occurs first, is recommended.

7.2.3 Hydrosphere

- **Ground Water**—Sampling and analysis of ground water from the accessible well sampling points in closest proximity to the exhumed trench(es), both onsite and offsite, should be included. These samples should be taken at the conclusion of exhumation activities and resumed to a quarterly schedule thereafter. Tritium and any other mobile and likely contaminants in ground water, should be performed. These other analyses might include nitrate ion (NO₃⁻), total dissolved solids and total organic carbon as useful additions for onsite samples as indicators of trench leaching, at least at the arid site. At least one onsite downgradient well must remain to provide continued leach detection.

- **Surface Water**—Collection and analysis (tritium is the most probable contaminant) of any free-standing water uncovered as part of the exhumation is a must. Nearby (within 3 km) surface bodies of water should also be sampled during the exhumation process for possible redeposition.

7.2.4 Soil and Vegetation

Existing operational requirements for soil and vegetation sampling will be continued, but with additional surface soil sampling to assure these activities have not increased surface soil contamination. Up to eight additional soil samples are suggested, ringing the trench from which waste was removed. Soil and vegetation samples are to include gamma scan analyses. Any sample result greater than two times the standard deviation of the most recent unaffected results for the same medium and location will be cause for the same follow-up actions as specified in previous sections.

7-4
7.2.5 Other Biota

Sampling of other biota is suggested for waste relocation activities. Suggested media would include any burrowing species observed in the vicinity of and during the exhumation. A gamma scan of the entire animal or at least of the edible flesh portion (if that specie is considered a food source for man in that region) should be included.

7.3 RELATIONSHIP TO CERTIFICATION TASK

Any decommissioning effort will not be complete without certification upon completion of the job. There are two roles to be considered as part of the certification process: 1) an ongoing process during the decommissioning operations which provides assurance that the decommissioning is performed according to the plan for that site, and 2) an independent survey to specify the radiological conditions of the site at the completion of decommissioning. The certification document itself will refer to all of the documents that were produced during the decommissioning, the final site radiological status in terms of concentrations, and a final set of environmental dose calculations based on those concentrations.

Statistical methods are required due to the inherent variability in radioactivity measurements collected at different locations and times, with different sampling methods or instruments. This variability implies some uncertainty in the knowledge of the actual average radioactivity levels present, and hence some possibility of making wrong decisions with regard to suitability for the unrestricted use of a decommissioned site/facility. In contrast with the "directed" surveillance programs shown in Section 6, site certification requires a statistically based program of "random" measurements. This affects the number or location of samples/measurements and the method of using the resulting data to make decisions and to estimate average radiological conditions.

Hence, implementation of the environmental monitoring programs recommended for decommissioning operations at the reference sites are insufficient to completely satisfy the requirements for site certification. It is expected that
existing licenses will be amended as needed to require submittal of site closure and stabilization plans. These will include explicit requirements for the license to be terminated and the material buried at the site to be transferred to custodial government care. New applicants will be required to submit preliminary site closure and stabilization plans as part of the initial application. In all cases, site stabilization is anticipated to occur following completion of trench filling or waste exhumation, and to be followed by site closure, either for a temporary "decay" period or for site certification (in the case of complete waste exhumation).

7.4 REFERENCES


8.0 QUALITY ASSURANCE

This section provides a discussion of the quality assurance (QA) measures and quality control (QC) procedures necessary in conducting environmental surveillance programs at low-level waste burial sites.

8.1 QUALITY ASSURANCE OBJECTIVE

The objective of quality assurance (QA) is to maintain the quality of the results of a program within established limits of acceptance. Although details and size of programs may differ, the basic elements of an adequate quality assurance program for environmental surveillance are applicable to all LLWBG sites. A QA program consists of all programmed events which are necessary to ensure the accuracy of the techniques and analyses, and provides the needed control, verification, and documentation at predetermined points throughout the program. Quality control (QC) procedures, on the other hand, are more task-specific and provide guidelines to ensure accuracy through established standards and procedures. QA provides the framework to ensure compliance with these task-specific QC guidelines, and should establish the needed QC on each phase of the surveillance program.

The size of an environmental surveillance program at a LLWBG site will be relatively small. A LLWBG surveillance program may only involve 1 to 3 people and it may be handled entirely by one or more subcontractors. It is important that a quality assurance plan be developed that addresses the quality requirements of each phase of the surveillance program whether performed in-house or by contractor. The responsibility for QC should be identified and provisions included to audit all phases of the program.

There are several useful guides for developing and evaluating QA programs.\(^{(1,2,3)}\) Regulatory Guide 4.15\(^{(4)}\) is particularly useful.

8.2 EQUIPMENT PROCUREMENT AND TESTING

Appropriate performance specifications (including range, sensitivity, precision, and environmental stresses) should be provided when purchasing any
equipment. To the extent applicable, national standards may be used or referenced. Reference (5) provides detailed guidance on quality assurance requirements for procurement of equipment and supplies with an extensive list of QA requirements and guidance documents available from national standards organizations and government agencies.

To the extent possible, acceptance testing should be performed; however, it will generally not be possible for the buyer to test an item over the full range of expected environmental stresses and reliance on the vendor's certification may be necessary. For radiation measuring equipment, initial calibrations and tests for response and precision should be performed. (6)

8.3 QUALITY CONTROL ON FIELD RADIATION MEASUREMENTS

It is essential that equipment be properly calibrated and that there be operational procedures to check that instruments used remain within calibration limits. (6) True calibrations, which involve comparison and adjustments to known quantities of radioactivity or radiation fluxes, are required infrequently after initial calibration. Calibration standards that are used should be traceable to the National Bureau of Standards whenever possible. Calibrations are required if there are replacements of major components of an instrument or if operational tests indicate a need for repair and recalibration. If a site does not have the capability to calibrate instruments, they will have to be sent to a service contractor. It is important to perform operational checks on instruments after they have been shipped and before they are issued for use.

Calibration procedures, whether in-house or contractor, should be documented and records kept on the maintenance and calibrations performed on each instrument. The date that an instrument should be returned to the shop for routine maintenance inspections and battery checks should be clearly indicated on the instrument. The length of time that an instrument can be used before recalibration varies. Laboratory instruments should be very stable and complete recalibration may not be needed for several years. In addition to field source checks before each use, portable instruments need more frequent shop inspections because of the stresses they are subjected to.
as well as problems associated with battery life. Typical shop inspection intervals for portable survey instruments are one to three months.

There should be written operational procedures for the use of all field monitoring equipment.

8.4 QUALITY CONTROL ON SAMPLING

The goal of a good sampling program is to obtain samples that are representative of the media being sampled. It is not possible to perform routine calibrations or simple precision checks on sampling; it is, therefore, essential to establish and adhere to written sampling procedures. The uncertainty in monitoring data that results from sampling errors can be much more significant than subsequent analytical errors, but careful adherence to a sampling plan and sampling procedures can minimize such errors. Written procedures provide guidance to monitoring personnel and also provide the basis for audits to ascertain that procedures are being followed. Procedures should include not only information on where and how to collect samples, but also instructions for packaging, preservation, and storage of samples. This is necessary to ensure the integrity of the samples from the time collected to the time they are actually analyzed.

When sampling bulk media like soil, there are no absolute methods; therefore, it is necessary to use standard or recognized methods for comparability of results. Most soil data are difficult to compare from site to site because of the different sampling methods used. Areas, depths, and profile are important considerations because the samples represent such a small portion of the area or volume being sampled and the vertical distributions may vary significantly with depth. The statistical design of sampling is, therefore, essential for site characterization. Considerable work has been done on sampling soil for plutonium analysis and extensive guidance and discussion are provided in References 9 and 10.
8.5 **ANALYTICAL QUALITY CONTROL**

The function of an analytical laboratory is to describe accurately the compositions of samples submitted for analysis. To accomplish this, quality control is necessary and is practiced to some degree in all laboratories.

It is likely that an analytical contractor will be used to analyze the samples collected. The laboratory should be required to observe proper analytical quality control procedures and provide a quality control plan. The plan should address:

1. written analytical procedures
2. calibration and background checks
3. analysis of spikes and blanks
4. duplicate analyses
5. participation in interlaboratory cross-checks
6. data reduction and verification procedures

There are several guides that can be used to assist in developing and evaluating an analytical QA program.\(^{11,12}\)

All QC data should become part of the QA documentation.

8.6 **DATA REVIEW AND COMPUTATIONAL CHECKS**

It is expected that each activity that produces data will incorporate data review procedures. These should provide review of measurement data for reasonableness and consistency as well as comparisons with quality control data. Criteria for recognizing deficiencies in data should be established and provisions made to document changes, since in many cases the raw data will be the inputs for subsequent calculations of concentrations, doses, releases, etc. All calculations, computer programs, or other methods of data handling should be recorded or referenced in laboratory notebooks or files in such a way that they can be followed by others.
8.7 PROCEDURAL AUDITS

A significant part of a quality assurance program are procedural audits. These are formal, independent evaluations of any operating procedures or criteria that directly or indirectly affect quality. To maintain objectivity and credibility audits should not be conducted by persons directly responsible for the activity which is being audited. An audit plan should define the objectives, determine data collection procedures, establish schedules and select audit teams. At the beginning of a project, all participants should know what quality characteristics are considered important and what will be evaluated.

8.8 REFERENCES


9.0 DOCUMENTATION AND RECORDS

This section addresses the documentation and records associated with the environmental surveillance program; however, it is assumed that other important records such as site property, receipts of shipments, burial locations, personnel exposure, and personnel records will be maintained in like manner. The need for these documents and records is based on experience to date at operating LLWBGs and at other licensed nuclear facilities in the U.S. A licensee (the holder of a license issued under the regulations in Chapter 1 of Title 10 of the Code of Federal Regulations) will have to maintain the records specified in the operating license and those that are required by applicable state and federal regulations. The records to be maintained on the environmental surveillance program should be:

1. Description of the Program
   This should include documentation of:
   a. The types of samples collected (air, water, soil, etc.)
   b. Sampling locations
   c. Sampling frequency
   d. Sample sizes
   e. Location, frequency, and type of external radiation measurements

2. Surveillance Data
   This should include the monitoring results, concentrations, and dose measurements, with the associated analytical errors, date, and locations.

3. Data Evaluation
   This should include all reported evaluations of the environmental surveillance data, evaluations of the site containment based on these data, or evaluations to demonstrate compliance with regulations concerning releases of contaminants from the site.

4. Quality Control Program
   (See Section 9.2)
9.1 RECORDS RETENTION

Records must be preserved for the period of long-term care, at least until a site is released for unrestricted use. Because administrative control of a burial site may be required for many years, it is important that burial ground records be accessible for this time period and that they be preserved in a useable form. Records would be stored in the form judged most appropriate by the responsible agency. Paper copies should be filed in a safe, protected area; they should be used only for temporary record storage. For long-term preservation of records, microfilms could be made; this would also reduce the need for filing space. For record preservation and ease of data evaluation, data requiring repeated, rapid retrieval could be stored in a computer bank as well as in the files.

An example of a program to preserve burial records and make them accessible for future reference was the program carried out at the Morehead, Kentucky (Maxey Flats), site under joint sponsorship of the Kentucky Radiological Health Department (KRHD) and the U.S. Environmental Protection Agency (EPA). The program pertained to the preservation and analysis of waste inventory records, but similar programs should be devised for site inspection and maintenance records and for environmental surveillance records. Under the KRHD-EPA program, information from the Maxey Flats Radioactive Shipment Records was transferred onto magnetic computer tape. The information covered waste burials for the period 1963 to 1972. Information coded onto computer tape included the burial date, the burial location (i.e., trench of burial), the isotope buried, the radioactivity of the buried isotope, and the volume of the waste material buried. A computer program was written that used the burial data and calculated the radioactivity of the waste as of the year 1974.

9.2 DOCUMENTATION REQUIREMENTS

Documentation for quality assurance in an environmental surveillance program includes, in addition to the data records:

- Quality Assurance plan
• Routine environmental surveillance procedures, including analytical procedures
• Records of participation in interlaboratory comparison studies
• Internal analytical quality control records (replicates, blanks, and spikes)
• Procurement acceptance records
• Audit, calibration and test records.

The routine environmental procedures may be embodied in a health physics manual or a separate environmental surveillance manual. In addition to the details of sample size and container, specified instrument, etc., each environmental procedure should include the important elements of good practice applicable to that measurement or sample and to the locations at which the procedure is used. With the use of the manual, an auditor should be able to determine that all important procedural requirements have been complied with. Environmental emergency procedures may either be included or documented separately.

The routine surveillance schedule may be included in the procedure manual or documented separately. The primary purpose of each measurement should be identifiable, whether for dose calculation, for trend evaluation, for quality assurance, or for some other purpose.

A description of the quality assurance program may also be part of the environmental procedures manual if not documented separately. This includes the required performance specifications for equipment, procured services, and calibration checks, a current listing of analytical audit samples and any cross-check programs, the current schedule for replicate sampling and procedural audits, and a description of the documentation and records system.

9.3 PUBLIC ACCESS TO LAND USE RECORDS

It is expected that records generated at the time of decommissioning, including certification of status and notice of license termination, will become part of the permanent docket and subsequently available to interested
members of the public on request. However, there is no guarantee at present that, at some distant date, a prospective purchaser of land that used to be a nuclear site would be made aware of this fact. Attaching a brief notice to the civil property records maintained in county (or the equivalent governmental unit) property record systems, and giving the docket number or file access code, would permit any prospective purchaser to become informed of such previous use. Even though the presumption is that any site which has been decommissioned and had its license terminated is safe for unrestricted public use, the public availability of the record should be of value.

9.4 REFERENCE

10.0 SUPPLEMENTAL BIBLIOGRAPHY

Listed below are several documents not specifically cited in the text but which may be useful in establishing an acceptable LLWBG monitoring program.


I. Y. Borg et al., Information Pertinent to the Migration of Radionuclides in Ground Water at the Nevada Test Site, Part I: Review and Analysis of Existing Information, UCRL-52078, Lawrence Livermore Laboratory, California, May 1976.


*Available for purchase from the NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission, Washington, DC 20555 and/or the National Technical Information Service, Springfield, VA 22161.
This Addendum supplements, and to some extent replaces, the preliminary description of environmental radiological surveillance programs for low-level waste burial grounds (LLWBG) used in the parent document, "Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground," NUREG/CR-0570. The Addendum provides additional detail and rationale for the environmental radiological surveillance programs for the two referenced sites and inventories described in NUREG/CR-0570. The rationale and performance criteria herein are expected to be useful in providing guidance for determining the acceptability of environmental surveillance programs for other inventories and other LLWBG sites.