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Recommendations to the NRC for Review Criteria for Alternative Methods of Low-Level Radioactive Waste Disposal

Environmental Monitoring and Surveillance Programs

Prepared by D.H. Denham, R.D. Stenner, P.A. Eddy
R.E. Jaquish, J.V. Ramsdell, Jr.

Pacific Northwest Laboratory

Prepared for
U.S. Nuclear Regulatory
Commission

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Prepared by
D.H. Denham, R.D. Stenner, P.A. Eddy
R.E. Jaquish, J.V. Ramsdell, Jr.

Pacific Northwest Laboratory
P.O. Box 999
Richland, WA 99352

Prepared for
Division of Low-Level Waste Management and Decommissioning
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555
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ABSTRACT

Licensing of a facility for low-level radioactive waste disposal requires the review of the environmental monitoring and surveillance programs. A set of review criteria is recommended for the U.S. Nuclear Regulatory Commission (NRC) staff to use in each monitoring phase--preoperational, operational, and postoperational--for evaluating radiological and selected nonradiological parameters in proposed environmental monitoring and surveillance programs at low-level waste disposal facilities. Applicable regulations, industry standards, and technical guidance on low-level radioactive waste are noted throughout the document. In the preoperational phase, the applicant must demonstrate that the environmental monitoring program identifies radiation levels and radionuclide concentrations at the site and also provides adequate basic data on the disposal site. Data recording and statistical analyses for this phase are addressed in relation to three basic issues: Are data recorded with accuracy in the proper units? Do data have estimates of uncertainty associated with them? And are the necessary descriptive statistics included? Quality assurance and reporting criteria are also specified. In the operational phase, the applicant must demonstrate that considerable care has been taken in designing and implementing the environmental monitoring programs and that data obtained during the first phase are reflected in the design of those programs. The operational phase must also be technically sound and broad enough to address potential issues that may be raised by the public. The postoperational phase requires continued sampling and measurements of those media that may provide a future exposure pathway to the public, perhaps at a reduced frequency during the long-term care period, based on the data obtained during the operational phase. Review checklists are provided for NRC use in evaluating the adequacy of environmental monitoring and surveillance programs for compliance with applicable regulations.

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This document is the result of a study (Task 1 in FY 1987 and Task 6 in FY 1988) performed by personnel of the Pacific Northwest Laboratory (PNL) in Richland, Washington, for the U.S. Nuclear Regulatory Commission (NRC), entitled, "Environmental Monitoring for Alternative Methods of Disposal of Low-Level Waste" (NRC Order 50-87-049, FIN B2484-7 and B2484-8). Dr. Robert Neel was the initial NRC project manager until April 13, 1987, at which time Dr. Banad Jagannath assumed that role. The PNL project manager was Dale Denham, with the technical assistance of Paul Eddy (hydrology), Richard Jaquish (quality assurance), Robert Stenner (statistics and nonradiological parameters), and Van Ramsdell (meteorology).

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EXECUTIVE SUMMARY

The Low-Level Radioactive Waste Policy Amendments Act of 1985 requires that the U.S. Nuclear Regulatory Commission (NRC) identify methods for the disposal of low-level radioactive waste other than shallow-land burial/disposal (the technique now used in the U.S.), establish and publish relevant technical information regarding those alternative methods that a state or state compact must provide to the NRC, and identify and publish technical requirements that such alternative facilities must meet if pursued as an alternative to shallow-land disposal.

This document recommends criteria that can be used by the NRC staff in reviewing the radiological and selected nonradiological parameters of environmental monitoring and surveillance programs proposed by license applicants for alternative low-level radioactive waste disposal facilities. These criteria are based on the requirements established in the U.S. Code of Federal Regulations (CFR), Title 10, Part 61. The environmental monitoring and surveillance programs that are addressed in this document are those included in the preoperational, operational, and postoperational phases in the life cycle of a disposal site.

Three alternative disposal methods are discussed in this document--earth-mounded concrete bunkers (EMCB), below-ground vaults (BGV), and augered shafts (AUS)--as previously determined by the NRC to be acceptable alternatives to shallow-land burial/disposal (SLB). With SLB, a trench is excavated, low-level waste containers are placed in the trench, the voids between containers and the walls of the trench are backfilled, and then the waste is covered with earth. An EMCB disposal facility for low-level radioactive waste would consist of an earth-mounded (tumulus) portion for disposal of Class A waste above the natural grade and a below-ground concrete bunker for disposal of Class B-C waste. The EMCB concept can also be designed with the concrete bunker and tumulus at separate locations. BGV refers to any enclosed, engineered structure that consists of reinforced concrete floors, walls, and roof located below the natural grade. AUS disposal facilities would consist of several components or features common to SLB, except that instead of using conventional scrapers for trench construction, drilling equipment would be used for shaft excavation. The primary differences between an AUS and the other two alternative methods would be in the preparation and completion of the site, as well as in the final depth of disposal; AUS would tend to be deeper than trenches (i.e., SLB), EMCB, or BGV.

The environmental monitoring activities specifically addressed in this document include the collection and analysis of samples of air, water (both surface and subsurface), rainwater, soil, sediment, flora and fauna, and the measurement of ambient radiation levels. Although data collection activities associated with site reconnaissance and site selection (such as studies of site ecology, meteorology, hydrology, geology, and seismology) are stipulated in the environmental monitoring section of the federal regulations, [10 CFR 61.53(a)], they are not included as part of the environmental monitoring and surveillance program review criteria provided in this document. However, the authors recognize that the information from these more in-depth studies may be especially useful in designing the preoperational program. The monitoring of effluents (i.e., in ventilation pipes or drains and sumps); the monitoring of personnel, equipment, and facilities during operations; predisposal control measures; and record-keeping associated with waste disposal operations are also not addressed in this document.

Radiological environmental monitoring programs are emphasized, although some brief mention of selected nonradiological parameters, especially in ground water, and of site surveillance activities are also included. The nonradiological parameters selected are based on the ground-water section of the NRC Environmental Standard Review Plan (NUREG-1300). In general, environmental monitoring, whether radiological or nonradiological, is concerned with quantitative measurements or analyses, while site surveillance activities are mostly qualitative.

Environmental monitoring programs are designed and implemented to evaluate the impact of site activities and the potential transport of contaminants to the environment. Preoperational environmental monitoring programs are used to determine the "background" or "baseline" levels of radiation and/or selected nonradiological constituents that exist in and around the proposed site and will be initiated at least 1 year before the start of construction, at which time the operational program takes effect. Environmental monitoring during the operational and postoperational periods requires the collection of environmental data to determine if the operation of the facility is in compliance with applicable regulations and, if not, to identify problem situations in a timely manner. The operational period is expected to last a minimum of 30 years, or until the last receipt of and emplacement of waste, while the postoperational period may extend for another century from the termination of operations. The postoperational period will involve two distinct periods of time, a short-term period of 5 years and a long-term period of 100 years. During the short-term period, site closure and stabilization activities are taking place, and the site operator is preparing the site for transfer to the property owner. The property owner then assumes the monitoring and surveillance responsibility for the balance of the 100-year, postoperational period. This latter period is primarily one of institutional control by the site owner, in which less frequent environmental monitoring activities are expected.

This document provides a narrative listing of the applicable regulations, as well as regulatory guides and industry standards that provide objectives and guidance to be considered in reviewing environmental monitoring programs for proposed low-level waste disposal facilities. Suggested sampling and analysis programs for each phase are provided based on illustrative sites located in arid and humid regions of the country. Although three alternative disposal methods were considered in addition to SLB, monitoring program differences are expected only as a result of site-specific differences, not because of differences in disposal methods.

A summary of environmental monitoring program requirements that can be used as a concise checklist (by reviewers) for determining applicants' compliance with review criteria are also provided in appropriate sections of this document.

1.0 INTRODUCTION

This document recommends criteria for review of environmental monitoring and surveillance programs, pursuant to the environmental requirements established in 10 CFR 61. This report is intended to be used by the U.S. Nuclear Regulatory Commission (NRC) staff in reviewing environmental monitoring and surveillance programs proposed by license applicants for low-level radioactive waste disposal facilities (LLWDFs). The environmental monitoring and surveillance programs for LLWDFs will consist of three phases--preoperational, operational, and postoperational--corresponding to the three phases in the life cycle of a disposal site. The monitoring programs for each phase should flow smoothly into one another from the preoperational period to the postoperational period.

1.1 BACKGROUND

The Low-Level Radioactive Waste Policy Amendments Act of 1985 requires that the NRC 1) identify methods for the disposal of low-level radioactive waste other than shallow-land burial/disposal, 2) establish and publish relevant technical information regarding those alternative methods identified by NRC that a state or regional compact must provide to the NRC, and 3) identify and publish technical requirements that such alternative facilities must meet if pursued as an alternative to shallow-land burial/disposal.

A draft "Branch Technical Position on Licensing of Alternative Methods of Disposal for Low-Level Radioactive Waste" (51 FR 7806) references the U.S. Army Corps of Engineers studies of alternative disposal methods (Bennett 1985; Miller and Bennett 1985; Warriner and Bennett 1985) and identifies the need for licensing guidance for other innovative disposal designs to be developed by the NRC and published in a timely manner.

The NRC staff will need to apply licensing criteria, performance objectives, and most of the technical requirements of 10 CFR 61 to proposed alternative disposal methods. The Amendments Act of 1985 also requires that the NRC complete all activities associated with the review, evaluation, and processing of any license application within 15 months of receipt of the application. In addition to the draft "Branch Technical Position," the NRC has also published a Standard Format and Content guide, NUREG-1199 (NRC 1987a); a Standard Review Plan, NUREG-1200 (NRC 1987b); and an Environmental Standard Review Plan, NUREG-1300 (NRC 1987c). The current versions, Rev. 0, of these documents are for shallow-land burial/disposal only. The revised versions, planned Rev. 1, of these documents will address shallow land burial and alternative methods of disposal. The review criteria presented in this document will assist the NRC staff in providing timely review of the license applications for LLWDFs using alternative disposal methods.

1.2 SCOPE

This document provides criteria for the NRC's review of proposed environmental monitoring programs (preoperational, operational, and postoperational) by applicants for LLWDFs. The environmental monitoring program review criteria provided in this document are primarily for radiological parameters in support of determining compliance with the applicable regulations (10 CFR 61 and 10 CFR 20). No similar review criteria for nonradiological constituents are provided, except that a listing of nonradiological parameters is identified for the hydrological cycle, because these measurements relate or could relate to the potential for migration of radionuclides. As appropriate, both humid and arid regions are considered as potential sites for LLWDFs.

The environmental monitoring activities specifically addressed in this document include the collection and analysis of samples of air, water (both surface and subsurface), rainwater, soil, sediment, flora and fauna, and the measurement of ambient radiation levels. The analyses of samples taken in what might be considered effluents (i.e., in ventilation pipes or drains and sumps) are not included as part of the environmental monitoring and surveillance programs identified in this document. These analyses are instead considered part of the operational or effluent monitoring programs proposed by the applicant and, hence, are not within the definition of environmental monitoring as used in this document.

Although data collection activities associated with site reconnaissance and site selection (such as studies of site ecology, meteorology, climate, hydrology, geology, geochemistry, and seismology) are stipulated in the environmental monitoring section of the regulations [10 CFR 61.53(a)], they are not included as part of the environmental monitoring and surveillance program review criteria provided in this document. However, the information from these more in-depth studies conducted by the applicant in defining and evaluating the basic environmental data on the disposal site characteristics may be especially useful in designing the preoperational program. The primary reason for excluding these data is that the techniques for the collection and the expertise required for their evaluation are significantly different than those required for collecting and evaluating radiological environmental data. Also, generally these site characterization studies are conducted once before or in conjunction with final site selection, as opposed to the more routine environmental monitoring activities that are conducted before and throughout the operational and postoperational periods of a LLWDF. In addition, personnel, equipment, and facilities monitoring during operations, predisposal control measures, and recordkeeping associated with waste disposal operations are not addressed in this document.

This document emphasizes radiological environmental monitoring, although some brief mention of selected nonradiological parameters, especially in ground water, and of site surveillance activities are also included. The nonradiological parameters selected are taken directly from Section 3.4.2.2 of the Environmental Standard Review Plan, NUREG-1300 (NRC 1987c). In general, environmental monitoring, whether radiological or nonradiological, is concerned with quantitative measurements or analyses, while site surveillance activities are mostly qualitative. The surveillance activities considered in this document include visual observations, such as looking for downed or damaged fences, earth mounds from burrowing animals, trapped surface water, or ground subsidence.

1.3 BASES FOR ENVIRONMENTAL MONITORING PROGRAMS

LLWDFs are provided to isolate certain low-level radioactive waste from the immediate environment. This document provides a listing of the objectives, applicable regulations, as well as regulatory guides and industry standards, and potential exposure pathways to be considered in reviewing environmental monitoring programs for LLWDFs. The data from these monitoring programs should provide one part of the environmental information needed to evaluate the effectiveness of the site in continuing to isolate the disposed waste.

For the purposes of this document, a typical LLWDF is assumed to include all of the land and buildings necessary to carry out waste disposal. The disposal site is that portion of the facility that is used for the disposal of waste and consists of a number of disposal units (or disposal cells) and a buffer zone. A disposal unit is a discrete portion of the disposal site into which waste is placed for disposal. A buffer zone is a portion of the disposal site that is controlled by the licensee and which lies under the site and between the boundary of the disposal site and any disposal unit. It provides controlled space to establish monitoring locations that are intended to provide an early warning of radionuclide movement. (See the Glossary for definitions of terms used in this document.)

The objectives, timing, and duration of each of the three environmental monitoring program phases included in this document are provided in this and the following section. By way of definition, each of these phases is assumed to occur within distinct periods of time, although they may be expected to differ by up to a few years for specific sites, especially for the preoperational and operational phases.

Preoperational environmental monitoring programs are expected to be initiated at least 1 year before submitting the license application for NRC review and to be continued through the 15-month NRC review period until low-level waste is brought to the site, at which time the operational program would be enacted. Strictly speaking, the operational radiological environmental monitoring program cannot be expected to begin until there is movement of radioactive materials, i.e., until low-level radioactive waste is received onsite. During the operational period, the licensee will receive waste from offsite sources and carry out disposal activities in accordance with applicable regulations and license conditions.

The operational environmental monitoring and surveillance period is expected to last a minimum of 30 years, or until the last receipt and emplacement of waste, while the postoperational monitoring and surveillance period will extend for another 100 years from the termination of disposal operations. The postoperational monitoring and surveillance period will involve a site closure and stabilization period, post-closure observation and maintenance period of approximately 5 years, and an active institutional control period.

During the site closure and stabilization period, the licensee will no longer receive waste from offsite sources and will perform the final activities required to prepare the disposal facility so that ongoing active maintenance will not be required during the institutional control period. However, some radioactive waste may be generated as part of decontamination and/or demolition of onsite grounds and structures. This waste must also be managed pursuant to applicable regulations and license conditions. During the closure period, the environmental monitoring program will continue, but will be adapted as necessary to the specific activities carried out, including closure-specific action levels. This period would normally be expected to last approximately 5 years beyond site closure and is intended to ensure that the site is stable and suitable for institutional control to be transferred to the site owner.

The institutional control period will begin when the disposal facility license is transferred to the state or federal agency that owns the site. Under the conditions of the transferred license, the owner will carry out a program of environmental monitoring to verify continued satisfactory performance of the disposal facility, physical surveillance to restrict access to the facility, and miscellaneous minor custodial activities. During this period, productive uses of the land might be permitted if those uses do not affect the stability of the site and its ability to meet the performance objectives. While the duration of the active institutional control period has no fixed limit, it should normally be assumed to last no more than 100 years.

1.4 ENVIRONMENTAL MONITORING OBJECTIVES

Environmental monitoring programs are designed and implemented to evaluate the impact of site activities and the potential transport of contaminants to the environment. There are many statements in the literature about the objectives of environmental monitoring (EPA 1972; Regulatory Guide 4.14; Corley et al. 1981; ICRP 1984), with only a few specific to LLWDF (Denham et al. 1981; Sedlet and Wynveen 1983). Environmental monitoring programs for LLWDFs should include sufficient sampling/measurement locations, sampling, and analyses to 1) provide information on environmental changes over time, 2) evaluate the actual or potential exposure to humans and the environment, and 3) demonstrate compliance with applicable regulations.

Preoperational environmental monitoring is used to determine the "background" or "baseline" levels of radiation and/or selected nonradiological constituents that exist in and around the proposed site. In collecting this environmental information, the applicant will need to consider a number of characteristics that are also collected and evaluated as part of the site characterization process. Site characterization itself is expected to be initiated some time (perhaps years) before the preoperational environmental monitoring program and is expected to involve the evaluation of new as well as historical information previously collected by others for the site region chosen by the applicant (e.g., hydrological, geological, and seismological data of the U.S. Geological Survey; and meteorological and climatological data of the National Weather Service or of the National Oceanic and Atmospheric Administration). Other site characteristics data that will be useful in planning and implementing the preoperational environmental monitoring program are the local ecology and geochemistry. Environmental monitoring during the operational and postoperational periods requires the collection of environmental data to determine if the operation of the facility is in compliance with applicable regulations and, if not, to identify problem situations in a timely manner.

A listing of the objectives of environmental monitoring at LLWDFs is summarized in Table 1.1. This table was derived from existing programs at commercial LLWDFs in the U.S., the draft "Technical Position Paper" (NRC 1988), and Regulatory Guides, and published environmental monitoring guides.

TABLE 1.1. General Objectives of Environmental Monitoring and Surveillance Programs at LLWDFs During Different Phases

Preoperational Phase	Operational Phase	Postoperational Phase
• Determine natural and manmade radioactivity patterns	• Determine environmental conditions (rad. and selected non-rad.) from site operations	Short-Term (5 yr)
• Estimate background radiation levels and radionuclide concentrations	• Assess actual or potential public exposure from site operations	• Evaluate performance of completed facility
• Determine existing levels of selected nonradiological constituents	• Demonstrate compliance with applicable regulations	• Assess impact of site closure/waste stabilization activities
• Determine relationships between *in situ* measurements and environmental concentrations	• Maintain environmental data base	• Evaluate effectiveness of site closure
		Long-Term (100 yr)
		• Demonstrate compliance with applicable regulations
		• Compare environmental conditions with potentially changing regulations

1.5 ALTERNATIVE LOW-LEVEL WASTE DISPOSAL SITES

Physical and operational characteristics of the three alternative LLWDFs are described in Section 1.6, along with shallow-land burial (SLB), the method currently used for commercial low-level waste (LLW) disposal in the U.S. Because differences in physical and operational characteristics are expected to exist among those alternatives, especially on the basis of location, this section provides a discussion of the environmental and operating characteristics at two sites illustrative of the geologic/climatologic extremes. These anticipated extremes are based on the actual characteristics at existing commercial LLW disposal sites.

1.5.1 Illustrative Disposal Site Characteristics

This section contains a summary of the common characteristics for the two illustrative sites, an arid western site and a humid eastern site, as previously described in the addendum to NUREG/CR-0570 (Denham et al. 1981). The radioactive waste inventory for each site is identical, while other parameters are chosen to be representative of existing conditions.

The climate, geology, and hydrology of the illustrative sites are described in the environmental surveillance addendum to NUREG/CR-0570 (Denham et al. 1981). The key assumptions/bases listed in that addendum to describe the illustrative LLW sites are summarized in Table 1.2.

Description of Illustrative Disposal Sites

The illustrative disposal sites are assumed to be located on an upland area of generally flat or gently rolling terrain. The total site area ranges from 100 to 200 acres, 50 to 60% of which contain the disposal trenches. The remaining land area is used for buildings, access roads, and a 100-m-wide buffer zone[(a)] around the site perimeter between the disposal trenches and the site boundary.

The total site capacity for waste is assumed to be 1.5×10^6 m^3, contained in 60 disposal units, 30 each of Class A and Class B-C waste. Other disposal characteristics for each of the alternative disposal methods are provided in Section 1.6.

Waste Inventory

The waste inventory is assumed to be composed of 40% (by volume) non-fuel-cycle waste and 60% reactor fuel-cycle waste.

The non-fuel-cycle waste comes mainly from hospitals, medical schools, and universities and colleges. It includes trash paper, packing material,

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(a) The NUREG/CR-0570 Addendum used only a 50-m buffer zone, but the Conceptual Design Report (Rogers and Associates 1987) uses the larger value of 100 m, which is used here.

TABLE 1.2. Characteristics of Illustrative Low-Level Waste Disposal Sites[a,b]

- 30 years continuous operation (waste receipt, burial, and covering) is assumed.
- Radwaste inventory is 60% fuel-cycle waste, 40% non-fuel-cycle waste.
- Waste volume contains less than 1% free liquids.
- Outer waste containers are nonradioactive.
- Wastes are packaged according to current U.S. Department of Transportation standards.
- sposal units/trenches are earth covered.
- .isposal units/trench covers are graded and seeded to promote drainage.
- Radioactive waste transport to site is by truck.
- Waste delivered to the site satisfies all waste characteristic requirements of 10 CFR 61.
- Access to the disposal area and a 100-m-wide buffer zone is restricted by a chain link fence.

(a) Adapted from Table 3.1-1 of environmental surveillance addendum to NUREG/CR-0570 (Denham et al. 1981) and Section 5.1, Site Layout, of the Conceptual Design Report (Rogers and Associates 1987).
(b) The chemical or pyrophoric hazards of wastes disposed at LLWDFs are not specifically considered in this document.

protective clothing, broken glassware, plastics, expended scintillation cocktail and vials, animal carcasses, obsolete equipment, and building rubble. The wastes, principally tritium and carbon-14, are estimated to have an average specific activity of less than 0.1 Ci/m^3.

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 iron-55, cobalt-60, and nickel-63 (from light-water reactor decommissioning), and the fission products cesium-134 and cesium-137.

1.5.2 Illustrative Site Environments

The alternative LLWDFs are postulated to be located on two illustrative sites, an arid western site and a humid eastern site. The climate, geology, and hydrology of the western and eastern sites are summarized in Table 1.3. These illustrative sites are assumed to represent the range of potential environmental conditions to be monitored during the preoperational, operational, and postoperational phases for the alternative disposal methods employed.

TABLE 1.3. Environmental Characteristics for Illustrative Arid and Humid Sites

Parameter	Arid Western Site	Humid Eastern Site
Mean Annual Precipitation	160 mm	900 mm
Average Annual Evaporation	165 mm(a)	660 mm
Surface Material	silt, sand, gravel	loess, till, clay, sand, gravel
Bedrock Material	basalt	shale, siltstone, coal
Surface Water		
Proximity	16 km	1 km
Flow rate	3.4 x 10^6 L/sec	220 L/sec
Ground Water		
Proximity (depth to)	60 m	10 m
Gradient	0.18%	5%
Average Velocity	200 m/yr	3.7 m/yr
Cation Exchange Capacity	20 to 80 meq/0.1 kg	20 to 30 meq/0.1 kg
Hydraulic Conductivity(b)		
Silt	9 x 10^{-7} m/sec	N/A(c)
Loess	N/A	9.5 x 10^{-7}
Till	N/A	3.5 x 10^{-4} to 6 x 10^{-6}
Sand	5 x 10^{-4} to 3 x 10^{-5}	5 x 10^{-4} to 3 x 10^{-5}
Shale	N/A	9.5 x 10^{-10}
Gravel	1 x 10^{-2} to 3 x 10^{-3}	N/A
Effective Porosity		
Silt	0.20	N/A
Loess	N/A	0.20
Till	N/A	0.20
Sand	0.30	0.30
Gravel	0.35	N/A
k_d(d)		
Cobalt	No Data	350 L/kg
Strontium	20 L/kg	10 L/kg
Ruthenium	400 L/kg	No Data
Cesium	100 L/kg	40 L/kg
Uranium	20 L/kg	No Data
Plutonium	200 L/kg	No Data
Americium	1200 L/kg	No Data

(a) It is believed that essentially all (here shown slightly greater than, but not considered statistically significant) precipitation returns to the atmosphere by evaporation (an evapotranspiration), based on measurements made since 1971.
(b) Todd 1980, pp. 71-72.
(c) Not Applicable.
(d) Distribution coefficients, K_d, for isotopes reported in the literature.

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

- low annual precipitation (<20 cm), with evaporation potentially exceeding precipitation
- 60- to 100-m depth to ground water
- soil with moderate-to-high hydraulic conductivity
- relatively long distance from disposal site to point of ground-water discharge into surface streams.

The humid, eastern site has a continental climate with widely ranging temperatures throughout 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 in the north, or by more moderate temperatures hovering around the freezing point and long rainy seasons in the south. Additional characteristics include:

- high annual precipitation (>100 cm)
- 10- to 15-m depth to ground water
- soil with low hydraulic conductivity
- relatively short distance from disposal site to point of ground-water discharge into surface streams

1.5.3 Potential Critical Exposure Pathways

Because the basic radiation standards (e.g., 10 CFR 20 and 10 CFR 61) are given in terms of dose to people, it is desirable to use the estimates of potential radiation exposure of the public from activities at LLWDFs to aid in the design and implementation of environmental monitoring programs. The potential exposures from radioactive waste disposed at the illustrative sites can occur either from individuals encountering the waste directly or from the waste migrating from its disposed location into the human environment. The migration of radionuclides from existing SLB sites has been investigated by Dana et al. (1980) and Mayer and Platt (1977). Even though the critical pathways may be much the same for each of the disposal alternatives and the two types of sites, the chain of events leading to human exposure will likely 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, site-specific parameters should be used to predict possible critical pathways and to estimate relative maximally exposed individual doses. The methodology presented in Volume 2 of the Onsite

Disposal of Radioactive Waste, NUREG-1101-1 (Neuder and Kennedy 1987), should be used to estimate radiation doses and to predict critical pathways using the site-specific parameters for each LLWDF site.

Water constitutes a major potential transport media for the migration of radioactivity from LLWDFs; therefore, hydrologic factors are emphasized. At both types of illustrative sites surface runoff can potentially carry contamination offsite, but this factor is of greater importance for the humid sites. At either type of 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 and reviewed by the NRC staff during the licensing process.

One of the key assumptions for the illustrative sites is that the radioactive wastes are received in containers free of surface contamination. However, past experience (Blanchard et al. 1978) has shown that contamination of surface 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 LLW disposal operations. Therefore airborne particulates are postulated to be a potential critical pathway for both arid and humid sites during the operational phase.

Direct radiation is considered the predominant path during normal operations (i.e., with no spills or ruptures of waste containers) and, like airborne particulates, should be included in environmental monitoring programs at arid as well as humid sites as a potential critical exposure pathway.

The illustrative site environmental characteristics provided in Table 1.3 indicate that ground-water flow velocity for the arid and humid sites differ markedly. Based on that hydrologic information, if contaminants reach the aquifer, the possibility of contaminated ground water migrating significantly (~500 m) beyond the boundaries of the humid site is minimal for approximately 30 years; however, the greater ground-water flow rate at an arid site might result in contaminants in ground water beyond its boundaries within 30 years. Because disposal practices limit waste volume to less than 1% free liquids, thereby precluding downward migration of contaminants, the contaminants should not reach the aquifer at an arid site either. Therefore, during the operational phase, ground water should not be a potential critical pathway for either arid or humid sites; however, the greater depth of the shaft disposal at a humid site could lead to a potential for ground-water contamination.

Similarly, ingestion of foodstuffs should not represent a critical pathway 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 because of disposal operations and the almost constant human presence. Therefore, the potential for contamination of flora and fauna, with subsequent transmittal to humans, is considered extremely small.

During the early postoperational phase, site closure activities may involve the movement of large quantities of soil to cover the disposal units/trenches. If no leakage or rupture of waste containers has occurred during operations, then the surface should be free of removable or resuspendable contamination. Under these circumstances the most significant pathway would be from ground water contaminated by leaking or migrating waste. However, as noted earlier, experience at existing LLW burial grounds (Dana et al. 1980; Mayer and Platt 1977) 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 only for SLB.

Direct radiation is not considered a critical pathway during the early postoperational phase for either arid or humid sites, because site closure activities add shielding to the already covered waste. Similarly, ingestion of animals or other foodstuffs is not considered to represent a critical pathway because the site is still inaccessible to the populace and the earth-moving operations should preclude the survival or presence of most plants and animals.

During the short-term care 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 disposed contaminants to the human environment, although the engineered structures expected to be used for the alternative disposal methods should preclude intrusion as a critical pathway. Similarly, ground-water contamination during this time is also predicted to be minimal for the humid site, and of even less consequence at the arid site.

No waste- or earth-moving activities are expected during the long-term portion of the postoperational period, and the presence of site-related personnel on the site is expected to be minimal, probably only as a result of infrequent surveillance. Access to the site is still limited, but, with only periodic surveillance, continuous control of access onto the site is difficult to ensure. Regulations do not require a consideration of deliberate intrusion; however, some contact of LLW by humans cannot be ruled out. Because of the integrity of the engineered structures, deliberate intrusion is not expected to represent a significant pathway. If waste migration does occur, it would more likely be through ground water.

1.6 ALTERNATIVE DISPOSAL FACILITIES

This section provides a basic characteristization of the three alternative disposal methods: 1) earth-mounded concrete bunkers (EMCB), 2) below-ground vaults (BGV), and 3) augered shafts (AUS). A summary of these characteristics for the three alternative disposal methods and for SLB are provided in Table 1.4. For each type of facility, the amount of land area will probably differ as will the depth of the excavations to be made before initiation of any disposal operations. Hence, this brief section will orient the reviewer and provide key points to be considered in the review of license

TABLE 1.4. Summary of Functional and Physical Characteristics of Shallow-Land Burial and Alternative Disposal Concepts[(a)]

Functional Characteristics	Shallow-Land Burial	Earth-Mounded[(b)] Concrete Bunker	Below-Ground Vault	Augered Shaft
Waste is disposed:	Below grade	Above grade[(c)] Below grade[(d)]	Below grade	Below grade
Waste cover is:	Shallow earth	Shallow earth[(c)] Earth and engineered concrete[(d)]	Engineered Concrete plus earth	Earth, engineered concrete, and steel cap
Structural stability is provided by:	Earth	Modules[(c)] Facility[(d)]	Facility	Concrete shafts
Voids between waste containers are filled with:	Non-structural material	Non-structural material[(c)] Cement[(d)]	Non-structural material	Non-structural material
Physical Characteristics				
Total site area (acres):	102	205-221	137	100-146[(e)]
Total disposal area (acres):	48	125-137	71	54-79
Class A waste disposal unit[(f)]				
Number of units:	30	30	30	
Height of waste in unit (ft):	21	23	22	
Thickness of soil cover (ft):	6.5	6.5	6.5	
Class B-C waste disposal unit[(g)]				
Number of units:	30	30	30	30
Height of waste in unit (ft):	12	8-23	15.5	30-50
Thickness of soil cover (ft):	16.5	6.5-16.5	10	16-20

(a) Based on details provided in Conceptual Design Report (Rogers and Associates 1987).
(b) Ranges of characteristics and/or values based on whether the wastes are colocated or not. Class A wastes are placed in an above-ground tumulus (earthen cover), while the much smaller volume of Class B and C wastes would be placed in a separate bunker (if colocated, the smaller areas would apply).
(c) Class A tumulus only.
(d) Class B and C below-ground bunker (with Class A tumulus top or with a separate earthen cover).
(e) Physical characteristics for the augered shaft disposal concept are taken from the modular concrete canister design, Chapter 10, of Rogers and Associates (1987), because the modular canisters are vertical cylinders arranged in shallow trenches, but are modified because of the greater depths (perhaps up to 100 ft or more depending on geographic location) of shafts than of trenches (Bennett 1985).
(f) Class A waste [10 CFR 61.56(a)] is generally of short half-life or low concentration and therefore presents the least hazard.
(g) Class B and C wastes [10 CFR 61.56(b)] are generally more toxic or longer-lived than Class A and hence must meet more rigorous requirements for disposal; Class C waste also requires additional measures at the disposal facility to protect against inadvertent intrusion.

applications for each of the alternative disposal methods presently considered acceptable by the NRC. These characteristics include not only the differences in methods of disposal, but also differences in the type of soil/climate regimes in which the proposed LLWDFs are to be sited. These latter characteristics are generally split between the arid and humid regions of the country.[a]

1.6.1 Earth-Mounded Concrete Bunkers (EMCB)

An EMCB disposal facility for low-level radioactive waste consists of two distinct disposal technologies that are used at the same site. The earth-mounded portion is for the disposal of Class A waste above grade with an earth cover (tumulus). The concrete bunker is designed for below-ground disposal of Class B-C waste. The EMCB concept can also be designed such that the concrete bunker and the tumulus are constructed at separate locations. The concrete bunker portion of the design allows the disposal of waste below ground, gives structural stability, and with the tumulus provides an additional intruder barrier. The tumulus portion of the design provides a disposal method that does not require below-ground construction. Figure 1.1 is an artist's conception of an EMCB disposal facility.

The EMCB approach to low-level radioactive waste disposal has been satisfactorily used in France for nearly 20 years, as reported in Volume 4 of NUREG/CR-3774 (Miller and Bennett 1985). In this approach, the possibility of inadvertent intrusion is minimized by the use of waste encapsulation and multiple barriers. Because of the barriers, infiltration of surface water is expected to be greatly retarded, resulting in a slow diffusion of radioactive ions through surrounding soils as probably the only mode of radionuclide migration, if any is to occur (Cherry and Gillham 1977; Gillham and Cherry 1983).

1.6.2 Below-Ground Vaults (BGV)

As used in this document, below-ground vault (BGV) refers to any enclosed, engineered concrete structure located below the natural grade. The structure will consist of reinforced concrete floors, walls, and roof. The BGV allows the disposal of wastes below ground, gives a structural stability, and with a concrete cover restricts the movement of water downward through the waste. The soil cover adds an additional barrier to infiltration of water into the waste, greatly reduces the likelihood of human, plant, or animal intrusion, and further reduces gamma exposure rates at the surface. Figure 1.2 is an artist's conception of a BGV disposal facility.

(a) Arid regions such as those found in the steppe-shrub regions of the west (Idaho, eastern Oregon, and Washington) and southwest (Nevada, Arizona, and New Mexico); humid regions such as those typical of the southeastern U.S.

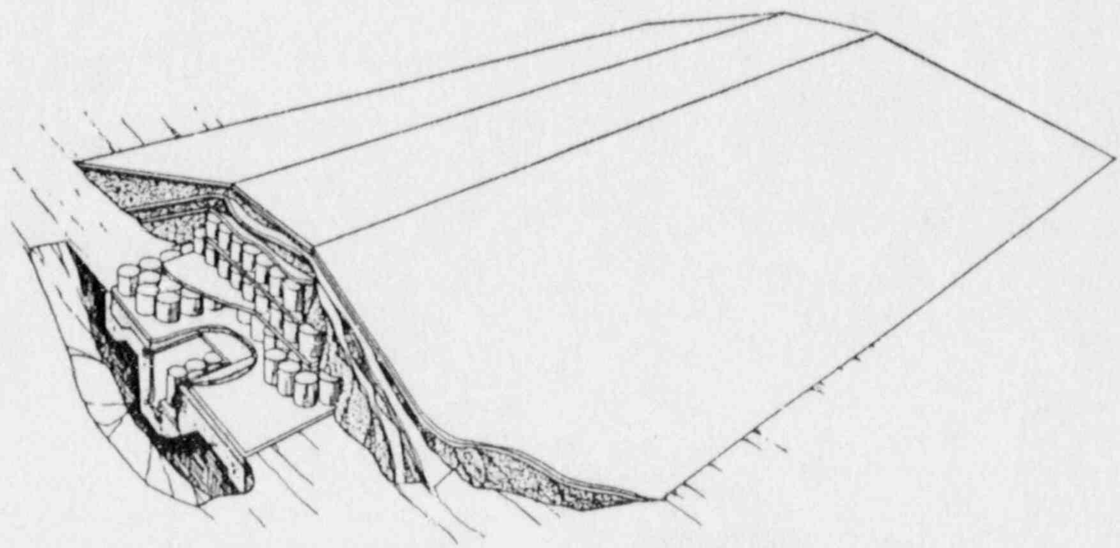


FIGURE 1.1. Artist's Conception of Earth-Mounded Concrete Bunker Low-Level Radioactive Waste Disposal Facility (Source: Figure 11-1 of Rogers and Associates 1987)

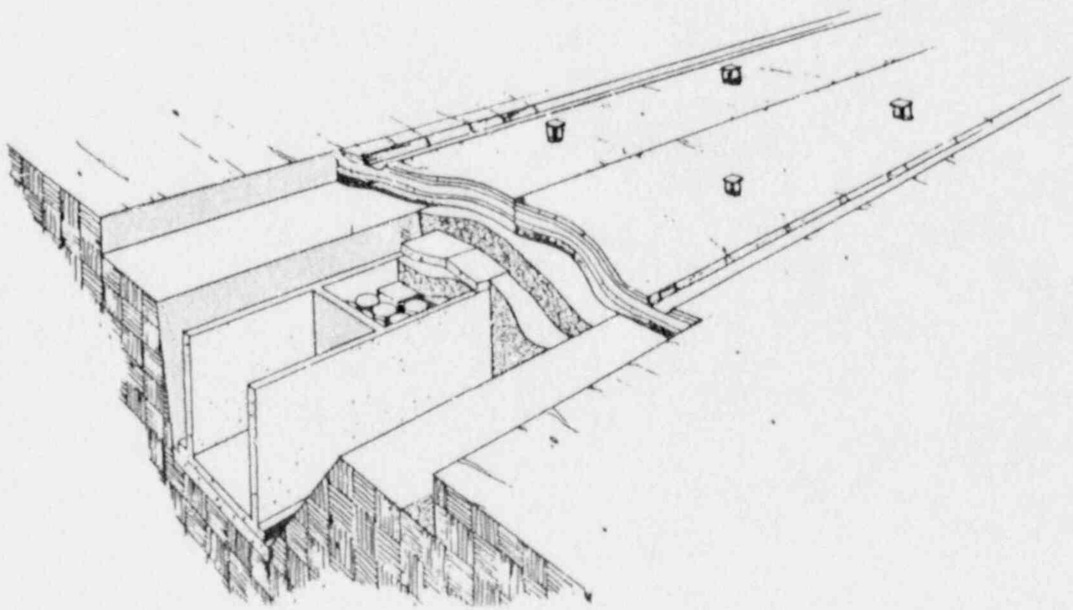


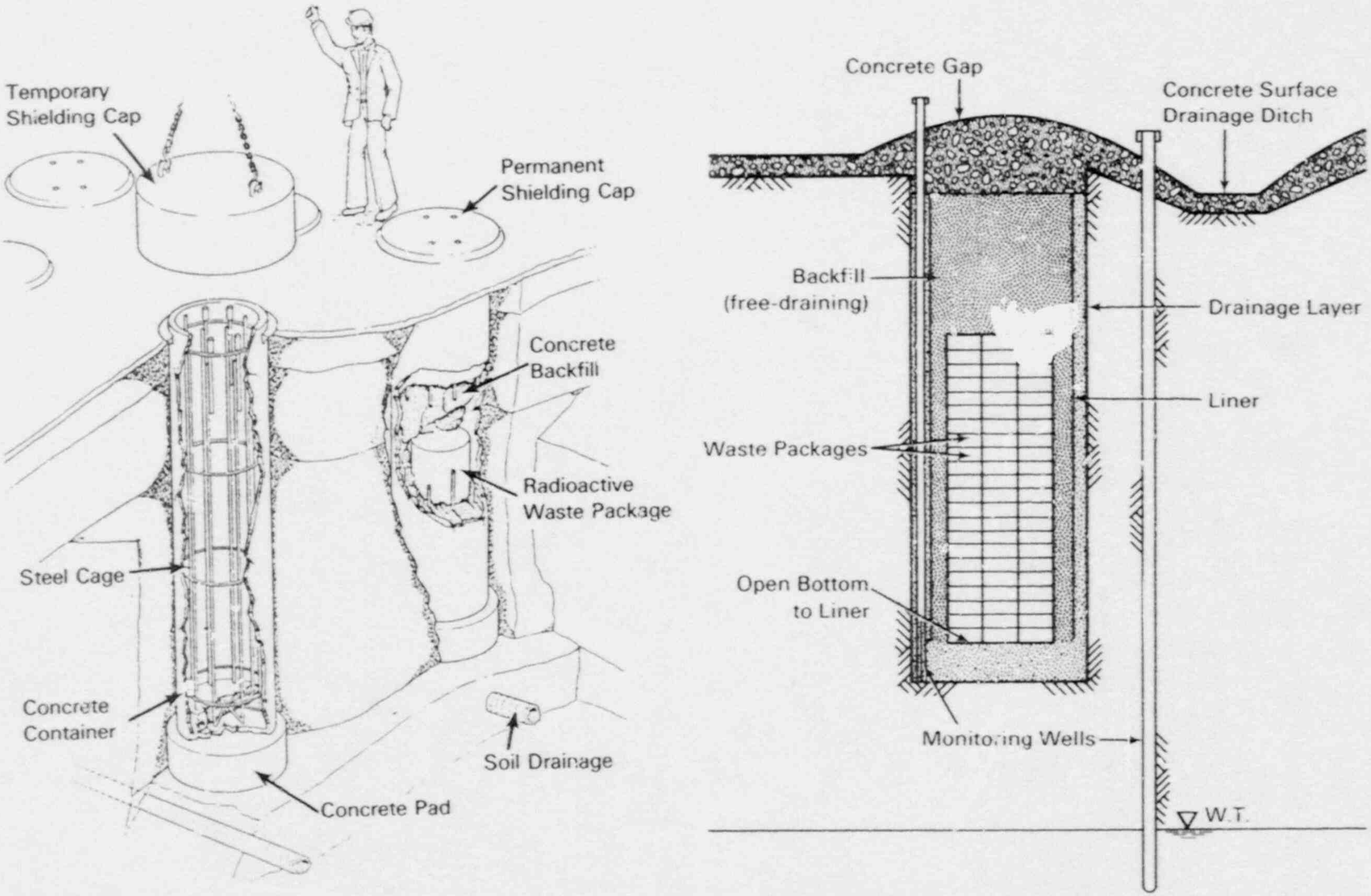
FIGURE 1.2. Artist's Conception of Below-Ground Vault Disposal (Source: Figure 8-1 of Rogers and Associates 1987)

Although BGVs have not been used for the disposal of LLW in the U.S., their design features should result in good long-term performance and serve to reduce the likelihood of environmental contamination, as reported in Volume 2 of NUREG/CR-3774 (Warriner and Bennett 1985). Their self-supporting structure reduces the potential for settlement or subsidence of the cover and also serves as an effective barrier to inadvertent intruders, plants and burrowing animals. The potential for damage from erosion or other surface geologic processes should be reduced because of the structure's integrity. Infiltration rates should be reduced by the roof and wall barrier and the low-permeability cover. Free-draining backfill placed around the vault promotes drainage of any infiltrating water away from the vault, thus reducing the likelihood of contact of water with the waste packages. Also, because of the shallow depth, there will be a greater distance from and less likelihood of contacting the ground water.

1.6.3 Augered Shafts (AUS)

A disposal facility for LLW that uses an AUS as the disposal units would consist of several components or features common to SLB. Instead of using conventional scrapers for trench construction, drilling equipment would be used for shaft excavation. It is also possible that shafts could be prepared in a trench fashion by setting concrete pipes vertically on concrete foundations previously provided with an under drainage system. This method is used in Canada to store ion exchange resins (Morrison 1974; Feraday 1982, 1983). Differences would exist in the methods of preparing and completing the site as well as in the final depth of disposal; AUS would tend to be deeper than trenches (i.e., shallow land), EMCBs, or BGVs. The increased depth of shafts would reduce the amount of water infiltrating the wastes from the surface, if the cover and backfill are compacted to prevent cracks from forming. Such cracks could short-circuit the cover and backfill protection and would provide preferential flow paths as noted in Volume 5 of NUREG/CR-3774 (Bennett 1985). Figure 1.3 includes an artist's conception of two types of AUS disposal systems, one a shallower tile hole and the other a deeper enhanced shaft.

AUS disposal systems are expected to involve the loading of waste packages into disposal shafts with a mobile crane and special lifting devices. The shafts are expected to be deep, compared to the depth of burial for EMCB, BGV, and SLB (see next section) disposal systems. Because of the projected operations, there is the potential for higher gamma ray exposure rates during handling than for the other disposal alternatives. In the absence of significant ground-water movement or infiltration of surface water, slow diffusion of radioactive ions through surrounding soils is probably the dominant mode of radionuclide migration (Cherry and Gillham 1977; Gillham and Cherry 1983). This slow diffusion and generally greater disposal depth help reduce the likelihood of radioactive materials released to the atmosphere at the surface. However, with the greater depth there will be a shorter distance to the ground water. Protection of individuals from inadvertent intrusion and prevention of plant and animal intrusion is expected to be achieved through the use of the greater disposal depth, thick covers, and the use of sealing plugs and caps.



a. Tile Hole System

b. Shaft with Enhanced Performance Features

FIGURE 1.3. Artist's Conception of Augered-Shaft Disposal Systems (Source: Figures 7 and 10 of Bennett 1985)

1.6.4 Shallow-Land Burial (SLB)

Shallow-land burial/disposal consists of an excavated trench in which the LLW containers are placed. The voids between containers and the walls of the trench are backfilled; however, only the backfill between the walls is compacted. When the trench is backfilled, the waste is covered with earth. A typical trench is excavated above the water table with sides shaped to have stable side-slopes. The trench floor is gently sloped and is provided with a system of drainage layers and drains. It is assumed that all water will be actively monitored and collected, if needed, from the drains through the active institutional control period. Figure 1.4 is an artist's conception of a SLB disposal facility.

The principal barriers to the release of radionuclides from a SLB site are the hydrogeologic characteristics of the site and the earthen cover over the waste packages. Protection of individuals from inadvertent intrusion and prevention of plant and animal intrusion is provided by the thickness of earthen cover. With minimal infiltration of surface and/or ground water, slow diffusion of radioactive ions through surrounding soils can be expected as in the other disposal alternatives.

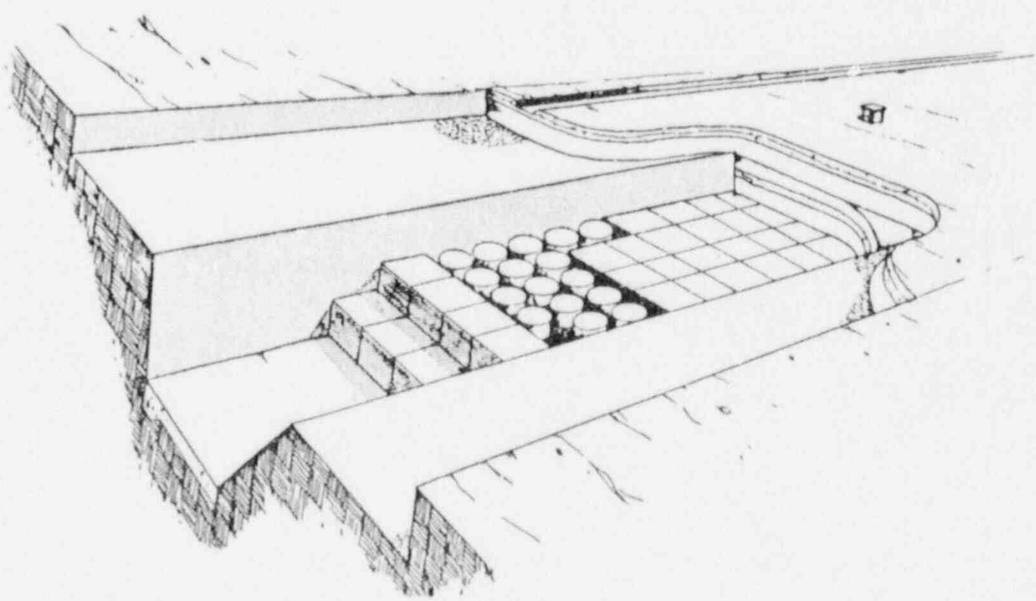


FIGURE 1.4. Artist's Conception of a Shallow-Land Burial/Disposal Facility (Source: Figure 6-1 of Rogers and Associates 1987)

1.7 REFERENCES

Bennett, R. D. 1985. Alternative Methods for Disposal of Low-Level Radioactive Wastes, Task 2e: Technical Requirements for Shaft Disposal of Low-Level Radioactive Waste. NUREG/CR-3774, Vol. 5, U.S. Nuclear Regulatory Commission, Washington, D.C.

Blanchard, R. L., D. M. Montgomery, H. E. Kolde, and G. L. Gels. 1978. Supplementary Radiological Measurements at the Maxey Flats Radioactive Waste Burial Site--1976 to 1977. EPA 520/5-78-011, U.S. Environmental Protection Agency, Montgomery, Alabama.

Cherry, J. A., and R. W. Gillham. 1977. "A Concept for Long-Term Isolation of Solid Radioactive Waste in Fine-Grained Deposits." In Proceedings of the Symposium on Management of Low-Level Radioactive Waste, pp. 1021-1040. M. W. Carter, ed., Pergamon Press, New York, New York.

Corley, J. P., D. H. Denham, R. E. Jaquish, D. E. Michels, A. R. Olsen, and D. A. Waite. 1981. A Guide For: Environmental Radiological Surveillance at U.S. Department of Energy Installations. DOE/EP-0023, U.S. Department of Energy, Washington, D.C.

Dana, R. H., V. S. Ragan, S. A. Molello, H. H. Bailey, R. H. Fickies, R. H. Fakundiry, and V. C. Hoffman. 1980. General Investigation of Radionuclide Retention in Migration Pathways at the West Valley, New York Low-Level Burial Site. NUREG/CR-1565, U.S. Nuclear Regulatory Commission, Washington, D.C.

Denham, D. H., P. A. Eddy, K. A. Hawley, R. E. Jaquish, and J. P. Corley. 1981. Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground - Environmental Surveillance Programs. NUREG/CR-0570 Addendum, U.S. Nuclear Regulatory Commission, Washington, D.C.

Federal Register, Title 51, Part 44 (51 FR 44), pp 7806-7810; "Branch Technical Position Statement on Licensing of Alternative Methods of Disposal for Low-Level Radioactive Waste" (Draft).

Feraday, M. A. 1982. "Canadian Experience with the Storage and Disposal of Low- and Intermediate-Level Wastes." In Proceedings of the Symposium on Low-Level Waste Disposal, pp. 411-429. NUREG/CP-0028, Vol. 3, U.S. Nuclear Regulatory Commission, Washington, D.C.

Feraday, M. A. 1983. "A Prospectus for the Development of Shallow Land Burial Disposal Concepts for the CRNL Site." Chalk River Laboratories Technical Record TR-307. Available from the Scientific Document Distribution Office, Atomic Energy of Canada Limited, Chalk River, Ontario, Canada.

Gillham, R. W., and J. A. Cherry. 1983. "Predictability of Solute Transport in Diffusion Controlled Hydrogeology Regimes." In Proceedings of the Symposium on Low-Level Waste Disposal, Facility Design, Construction, and Operating Practices, pp. 379-410. NUREG/CP-0028 (CONF 820911), Vol. 3, U.S. Nuclear Regulatory Commission, Washington, D.C.

International Commission on Radiological Protection (ICRP). 1984. Principles of Monitoring for the Radiation Protection of the Population. ICRP Publication 43, Pergamon Press, Oxford, England.

Low-Level Radioactive Waste Policy Amendments Act of 1985. Pub. Law 96-573, Dec. 22, 1980, 94-FTAT 3347 (Title 42, ¶ 2021b-2021d).

Mayer, P. G., and R. B. Platt. 1977. "The Fate of Radionuclides in the Barnwell Hydrosphere--A Case Study." Paper presented at Radioactive Effluence from Nuclear Fuel Processing Plant Seminar. Paper No. 24, AED-CONS-77-473-033, Karlsruhe, Germany. (Available from National Technical Information Service.)

Miller, W. O., and R. D. Bennett. 1985. Alternative Methods for Disposal of Low-Level Radioactive Wastes, Task 2c: Technical Requirements for Earth Mounted Concrete Bunker Disposal of Low-Level Radioactive Waste. NUREG/CR-3774, Vol. 4, U.S. Nuclear Regulatory Commission, Washington, D.C.

Morrison, J. A. 1974. AECL Experience in Managing Radioactive Wastes from Canadian Nuclear Reactor. AECL-4707, Atomic Energy of Canada Limited. Available from the Scientific Document Distribution Office, Atomic Energy of Canada Limited, Chalk River, Ontario, Canada.

Neuder, S. M., and W. E. Kennedy, Jr. 1987. Onsite Disposal of Radioactive Waste - Methodology for the Radiological Assessment of Disposal by Subsurface Burial. NUREG-1101-1, Vol. 2., U. S. Nuclear Regulatory Commission, Washington, D.C.

Regulatory Guide 4.14, Rev. 1. (1980); "Radiological Effluent and Environmental Monitoring at Uranium Mills." U.S. Nuclear Regulatory Commission (NRC), Office of Standards Development, Washington, D.C.

Rogers and Associates Engineering Corporation. 1987. Conceptual Design Report, Alternative Concepts for Low-Level Radioactive Waste Disposal. DOE/LLW-60T, U.S. Department of Energy, Washington, D.C.

Sedlet, J., and R. A. Wynveen. 1983. Low-Level Radioactive Waste Management Handbook Series - Environmental Monitoring for Low-Level Waste-Disposal Sites. DOE/LLW-13Tg, U.S. Department of Energy, Washington, D.C.

Todd, D. K. 1980. Groundwater Hydrology, 2nd Edition. John Wiley and Sons, Inc., New York, New York.

U.S. Code of Federal Regulations, Title 10, Part 20 (10 CFR 20); "Standards for Protection Against Radiation."

U.S. Code of Federal Regulations, Title 10, Part 61 (10 CFR 61); "Licensing Requirements for Land Disposal of Radioactive Waste."

U.S. Environmental Protection Agency (EPA). 1972. Environmental Radioactivity Surveillance Guide. ORP/SID 72-2, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1987a. Standard Format and Content of a License Application for a Low-Level Radioactive Waste Disposal Facility. NUREG-1199, U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1987b. Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility, Safety Analysis Report. NUREG-1200, U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1987c. Environmental Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility, Environmental Report. NUREG-1300, U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988 (Draft). "Technical Position Paper - Environmental Monitoring of Low-Level Radioactive Waste Disposal Facilities." U.S. Nuclear Regulatory Commission, Division of Low-Level Waste Management and Decommissioning, Washington, D.C.

Warriner, J. B., and R. D. Bennett. 1985. Alternative Methods for Disposal of Low-Level Radioactive Wastes, Task 2a: Technical Requirements for Belowground Vault Disposal of Low-Level Radioactive Waste. NUREG/CR-3774, Vol. 2, U.S. Nuclear Regulatory Commission, Washington, D.C.

2.0 APPLICABLE REGULATIONS AND GUIDANCE

The licensing requirements for a low-level radioactive waste disposal facility (LLWDF) are found primarily in 10 CFR 61 and in specific sections of the radiation protection standards in 10 CFR 20. Although not enforceable by the U.S. Nuclear Regulatory Commission (NRC), 40 CFR 61, Subpart I ["National Emission Standard for Radionuclide Emissions from Facilities Licensed by the Nuclear Regulatory Commission (NRC) and Federal Facilities Not Covered by Subpart H"] and any other potentially applicable Subparts, contain U.S. Environmental Protection Agency (EPA) regulations that may influence LLWDF operations. In addition, there are a number of NRC regulatory guides, NRC technical position statements, industry standards, and other documents that provide guidance to licensees on environmental monitoring methods and practices that should be applied at LLWDFs.

The preoperational environmental monitoring program (in addition to the preliminary site characteristics assessment) is necessary to understand the sensitive radiological and selected nonradiological aspects of a site. In designing the preoperational program, it is essential that the applicant consider the fact that many of the sampling locations and analyses chosen for the preoperational program will be utilized during the operational and postoperational phases. Hence, the preoperational environmental monitoring program must be designed to adequately assess the potential impact the disposal operations at the site may have on the environment in the future. While it is expected that the information collected may vary considerably among site applications, it is important that the applicant address the environmental monitoring program phases as completely as possible, considering the availability of data and the environmental sensitivities associated with the proposed site. For example, it can be reasonably concluded that ground-water aging is unnecessary at an arid site where disposal will take place far above the water table. However, this information is vital to the evaluation of any plan for disposal below the water table. The requirement for collection of seasonally variable data for at least a 12-month period is to ensure that seasonally high data points are not missed in the data set. Also, there may be cases where a 12-month collection period is not sufficient, as in the tracking of water table fluctuations, for example. In such cases, longer periods of collection time or the use of other records may be necessary.

This section provides a compilation of the regulations and guidance applicable to LLWDFs. It is intended for use as a concise reference of the bases for license application review criteria. The section is subdivided as follows: Sections 2.1 and 2.2 itemize the specific requirements of NRC regulations (10 CFR 61 and 10 CFR 20); Section 2.3 provides listings of applicable NRC regulatory guides and technical position statements; and Section 2.4 identifies industry standards and other general guidance documents.

2.1 10 CFR 61 - LICENSE REQUIREMENTS FOR LAND DISPOSAL OF RADIOACTIVE WASTE

Title 10, Part 61, of the U.S. Code of Federal Regulations (CFR) establishes, for land disposal of radioactive waste, the procedures, criteria, terms, and conditions upon which the NRC issues licenses for the disposal of radioactive wastes containing byproduct, source, and special nuclear material received from other persons. The regulations applicable to the areas of license review are included in specific sections of 10 CFR 61.11 through 61.81. A discussion of each section that applies to environmental monitoring follows.

2.1.1 10 CFR 61.7 - Concepts

Subsection 61.7(c), the "Licensing Process," subparagraph (3), requires the licensee to remain at the site for a 5-year post-closure observation and maintenance period to assure that the site is stable and ready for institutional control; subparagraph (4) requires the site-owner to carry out a program of monitoring to assure continued satisfactory disposal site performance.

2.1.2 10 CFR 61.11 - General Information

Subsection 61.11 describes the general information required for any land disposal [i.e., earth-mounded concrete bunker (EMCB), below-ground vault (BGV), augered shaft (AUS), or shallow land burial (SLB)] of wastes containing or contaminated with source, byproduct, or special nuclear material. An application for a license to operate a LLWDF must contain the following information at a minimum:

- identity of the applicant, including descriptions of business, location, and names of partners and/or principal officers and addresses that apply
- qualifications of the applicant's staff, including training and experience, plus a description of the organizational structure and/or lines of authority and assignments of responsibility, and a description of the personnel training program (see Section 3.2 in this document for recommendations)
- description of the site location, proposed activities, types and quantities of radioactive waste to be handled, other land use besides the disposal facility, and a description of the facilities and equipment
- proposed schedules for construction, receipt of waste, and first emplacement of waste at the proposed facility.

2.1.3 10 CFR 61.12 - Specific Technical Information

Subsection 61.12 states that an application must describe the natural and demographic disposal site characteristics, design features of the facility, principal design criteria, relationship of the design and natural events, codes and standards applicable to the design and construction of the facility, construction and operation, closure plan, natural resources at the site, radioactive material to be processed, the quality control program, the radiation safety control and monitoring program, and the environmental monitoring program.

2.1.4 10 CFR 61.13 - Technical Analyses

Subsection 61.13 discusses the specific technical information that must be included to demonstrate that the performance objectives of Subsections 61.40 through 61.44 (Subpart C) are met. Four sets of analyses are required, three of which are for site characterization, and only one for environmental monitoring. The environmental monitoring information includes the need for evaluation of radionuclide transport via air, soil, ground water, surface water, plant uptake, and exhumation by burrowing animals to demonstrate protection of the general population from releases of radioactivity. The analyses must clearly:

- identify and differentiate between the functions performed by the natural disposal site characteristics and those performed by the design features in isolating and segregating the wastes
- demonstrate that there is reasonable assurance that the exposure to humans from the release of radioactivity will not exceed the limits set forth in Subsection 61.41 (see Section 2.2.5 of this document).

2.1.5 10 CFR 61.29 - Post-closure Observation and Maintenance

Subsection 61.29 specifies that the licensee maintain a monitoring program at the disposal site for 5 years following closure; a shorter or longer time period for post-closure observation and maintenance may be established and approved, based on site-specific conditions.

2.1.6 10 CFR 61.30 - Transfer of License

Subsection 61.30(a)(4) provides the requirement that the post-closure monitoring program be operational for implementation by the site owner (i.e., following the short-term postoperational or 5-year post-closure period).

2.1.7 10 CFR 61.40 - General Requirement

Subsections 61.40 through 61.44 are combined in the regulations as Subpart C, Performance Objectives. Subsection 61.40 provides the general requirements for the siting, design, operation, closure, and control of land disposal facilities so that reasonable assurance exists that exposures to humans are within the limits established in the performance objectives in Subsections 61.41 through 61.44.

If the migration of radionuclides into the environment results in noncompliance with the performance objectives of Subsections 61.40 through

61.44, documented plans for taking necessary corrective measures are necessary to ensure timely and adequate response to potential noncompliance problems. To meet good practice standards, the action plan should specify proposed methods and equipment to be used for a representative suite of failure scenarios, as well as a time table for mobilization. This requirement is keyed to the size of the buffer zone, so that reaction and implementation of the planned action can be effected before contaminants migrate beyond the site boundary.

2.1.8 10 CFR 61.41 - Protection of the General Population from Releases of Radioactivity

Subsection 61.41 details the radiation exposure limits to people and establishes an ALARA (as low as reasonably achievable) philosophy as follows:

- Concentrations of radioactive material, which may be released to the general environment in ground water, surface water, air, soil, plants, or animals, must not result in an annual dose exceeding an equivalent of 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ of any member of the public.

- Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable.

2.1.9 10 CFR 61.42 - Protection of Individuals from Inadvertent Intrusion

Subsection 61.42 requires that the design, operation, and closure of the land disposal facility must ensure protection of any individual inadvertently intruding into the disposal site, occupying the site, or contacting the waste at any time after active institutional controls over the disposal site are removed.

2.1.10 10 CFR 61.43 - Protection of Individuals During Operations

Subsection 61.43 details the radiation protection criteria during operations as well as the need for the ALARA philosophy to be carried out:

- Operations at the land disposal facility must be conducted in compliance with the standards for radiation protection set out in 10 CFR 20, except for releases of radioactivity in effluents from the land disposal facility, which shall be governed by 10 CFR 61.41 (see Subsection 2.2.5 of this document).

- Every reasonable effort shall be made to maintain radiation exposures as low as is reasonably achievable.

2.1.11 10 CFR 61.44 - Stability of the Disposal Site After Closure

Subsection 61.44 emphasizes the long-term need for surveillance and/or minor custodial care rather than environmental monitoring. It requires that the disposal facility be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate to the extent practicable the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required.

2.1.12 10 CFR 61.53 - Environmental Monitoring

Subsection 61.53 contains six specific requirements to which an applicant must comply:

- At the time a license application is submitted, the applicant shall have conducted a preoperational monitoring program to provide basic environmental data on the disposal site characteristics. This information must address the ecology, meteorology, climate, hydrology, geology, geochemistry, and seismology of the disposal site. For those characteristics that are subject to seasonal variation, data must cover at least a 12-month period.

- The licensee must have plans for taking corrective measures if migration of radionuclides would indicate that the performance objectives in 10 CFR 61.40 through 61.44 may not be met.

- During disposal facility site construction and operation, the licensee shall maintain a monitoring program. This monitoring program must provide data to evaluate the potential health and environmental impacts during both the construction and operation of the facility and to enable the evaluation of long-term effects and the need for mitigative measures.

- The operational monitoring system must be capable of providing early warning of releases of radionuclides from the disposal site before the releases leave the site boundary.

- After the disposal site is closed, additional surveillance of the site shall include a monitoring system based on the operating history and the closure and stabilization of the disposal site.

- The post-closure monitoring system must be capable of providing early warning of releases of radionuclides from the disposal site before the releases leave the site boundary.

Because the licensee is required to maintain a monitoring program adequate to evaluate the potential health and environmental impacts and evaluate long-term effects and the need for mitigative measures, the requirement emphasizes the importance and need for environmental monitoring during construction as well as operation of the site. This requirement re-emphasizes the need for the capability to detect and control any releases of contaminants before they reach the site boundary.

2.1.13 10 CFR 61.70 - Scope

Subsection 61.70 and the three that follow it in the regulations are known as Subpart F, "Participation by State Governments and Indian Tribes." These subsections describe mechanisms through which the NRC will implement a formal request from a state or tribal government to participate in the review of a license application for a land disposal facility, which may include the review of an applicant's proposed environmental monitoring program.

2.1.14 10 CFR 61.80 - Maintenance of Records, Reports, and Transfers

Subsection 61.80 and the three that follow it in the regulations are known as Subpart G--"Records, Reports, Tests, and Inspections." These subsections describe the licensee requirements for annual reports (61.80), the tests to be performed by the licensee or NRC (61.81), the NRC site and/or records inspections (61.82), and the method NRC will implement in the case of any violations of the Atomic Energy Act of 1954, as amended, or any regulation or order issued thereunder (61.83). Item (i) of subsection 61.80 provides the specific requirements for submission of annual reports to the NRC; these reports are to include the results of the environmental monitoring program and are to be submitted by the end of the first calendar quarter of each year for the preceding year.

2.2 10 CFR 20 - STANDARDS FOR PROTECTION AGAINST RADIATION

The regulations of 10 CFR 20 provide the standards for protection against radiation hazards in both restricted and unrestricted areas. The monitoring programs for the three alternative methods of LLW disposal must meet the requirements of this regulation and a license application must address each of the requirements. In addition to addressing each item above the applicant's monitoring programs must be capable of documenting compliance with these requirements. This section summarizes the requirements from 10 CFR 20 that pertain to environmental monitoring.

2.2.1 10 CFR 20.105 - Permissible Levels of Radiation in Unrestricted Areas

Subsection 20.105 defines the conditions that must be met for approval of a license application involving levels of radiation in unrestricted areas. These conditions are as follows:

- Applications must report anticipated average radiation levels and anticipated occupancy times for each unrestricted area involved.
- The applicant must demonstrate the unlikelihood that any individual could receive from site operations a dose in excess of 0.5 rem to the whole body in any period of 1 calendar year.

- The licensee must not possess, use, or transfer licensed material in a manner that will create radiation levels which could result in an individual receiving a dose in excess of 2 mrem in any 1 hour, or 100 mrem in any 7 consecutive days, if that individual were continuously present in the area.

2.2.2 10 CFR 20.106 - Radioactivity in Effluents to Unrestricted Areas

Subsection 20.106 provides limits on the release of radioactive effluents to unrestricted areas. The specific requirements are summarized below:

- Radioactive effluents released to an unrestricted area must not exceed the concentrations specified in 10 CFR 20, Appendix B, Table II. Concentrations may be averaged over a period not greater than 1 year.

- The concentration limits of 10 CFR 20, Appendix B, Table II, apply at the boundary of the restricted area. The concentration of radioactive material discharged through a stack, pipe, or similar conduit may be determined with respect to the point where the material leaves the conduit. If the conduit discharges within the restricted area, the concentration at the boundary may be determined by applying appropriate factors for dilution, dispersion, or decay between the point of discharge and the boundary.

- The daily intake of radioactive materials from air, water, or food by a suitable sample of an exposed population group, averaged over a period not exceeding 1 year, must not exceed the daily intake resulting from continuous exposure to air or water containing one-third the concentration of radioactive materials specified in 10 CFR 20, Appendix B, Table II.

2.2.3 10 CFR 20.201 - Surveys

In these regulations, "survey" means evaluating the radiation hazards incident in relation to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation under a specific set of conditions. Subsection 20.201 stipulates that, when appropriate, such evaluation include a physical survey of the location of materials and equipment, and measurements of levels of radiation or concentrations of radioactive material present. The regulation states:

- The licensee shall make such surveys as may be necessary to comply with the regulations of 10 CFR 20 and are reasonable under the circumstances to evaluate the extent of radiation hazards that may be present.

2.2.4 10 CFR 20.401 - Records Of Surveys, Radiation Monitoring, and Disposal

Subsection 20.401 states that the survey and monitoring records and the maintenance and disposal of such records, applicable to environmental monitoring, shall be regulated as follows:

- Each licensee shall maintain records in the same units used in 10 CFR 20, showing the results of surveys.
- Records of the results of surveys shall be preserved for 2 years after completion of the survey or as authorized by the commission.
- Records of the results of surveys used to evaluate the release of radioactive effluents to the environment shall be maintained until the NRC authorizes their disposition.
- Records that shall be maintained may be the original or a reproduced copy or microform, if such reproduced copy or microform is duly authenticated by authorized personnel and the microform is capable of producing a clear and legible copy after storage for the period specified by NRC regulations.
- If there is a conflict between the NRC's regulations in this part (10 CFR 20), the license condition, the technical specification, or other written NRC approval or authorization pertaining to the retention period for the same type of record, the retention period specified in the regulations in this part shall apply unless the NRC has granted specific exemption.

2.2.5 10 CFR 20.403 - Notifications of Incidents

Subsection 20.403 identifies the types of incidents involving byproduct, source, or special nuclear material that require reporting to the NRC as specified by 10 CFR 20.405 (see Section 2.2.6, below). Those incidents that require notification, as related to environmental monitoring, include:

- Each licensee shall immediately report any events that may have caused or threaten to cause radiation exposure of the whole body of any individual equal to or exceeding 25 rems (whole body), 150 rems (skin), or 375 rems (extremities); or the release of radioactive material in concentrations which, if averaged over a period of 24 hours, would exceed 5,000 times the limits specified for such materials in Appendix B, Table II of 10 CFR 20.
- Each licensee shall, within 24 hours of discovery of the event, report any event that may have caused or threatens to cause radiation exposure of the whole body of any individual equal to or exceeding 5 rems (whole body), 30 rems (skin), or 75 rems (extremities); or the release of radioactive material in concentrations which, if averaged over a period of 24 hours, would exceed 500 times the limits specified for such materials in Appendix B, Table II of 10 CFR 20.

2.2.6 10 CFR 20.405 - Reports of Overexposures and Excessive Levels and Concentrations

The Subsection 20.405 requirements for reporting of overexposures or excessive levels or concentrations that relate to environmental monitoring are summarized below:

- A licensee shall make a report in writing within 30 days to the U.S. Nuclear Regulatory Commission, Document Control Desk, Washington, D.C. 20555, with a copy to the appropriate NRC Regional Office, of levels of radiation or concentrations of radioactive material (whether or not involving excessive exposure of any individual) in an unrestricted area in excess of 10 times any applicable limit set forth in 10 CFR 20 or in the license.

- Each report required shall describe the extent of exposure of individuals to radiation or to radioactive material, levels of radiation and concentrations of radioactive material involved, the cause of the exposure, and corrective steps taken or planned to ensure against a recurrence.

2.3 NRC REGULATORY GUIDES AND TECHNICAL POSITIONS

NRC guidance to aid an applicant in meeting the requirements of 10 CFR 61 and 10 CFR 20 is provided in the NRC regulatory guides and technical position papers identified in this subsection.

2.3.1 NRC Regulatory Guides

The following regulatory guides provide guidance to the applicant in meeting the environmental monitoring requirements of 10 CFR 61:

- Regulatory Guide 4.5, "Measurements of Radionuclides in the Environment, Sampling and Analysis of Plutonium in Soil," as it relates to techniques of soil sampling and soil sample preparation

- Regulatory Guide 4.13, "Performance, Testing, and Procedural Specifications for Thermoluminescence Dosimetry: Environmental Applications," as it relates to procedures for calibration, field application, and reporting of environmental dosimetry

- Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment," as it relates to quality control of all phases of the program (e.g., organizational structure, responsibility of personnel, records, operating procedures, sampling, and radioanalytical analyses)

- Regulatory Guide 8.2, "Guide for Administrative Practices in Radiation Monitoring," as it relates to guidance on administrative practices associated with radiation monitoring programs

- Regulatory Guide 8.6, "Standard Test Procedure for Geiger-Müller Counters," as it relates to testing the operating characteristics of Geiger-Müller counters before making calibrations and measurements

- Regulatory Guide 8.21, "Health Physics Surveys for Byproduct Material at NRC Licensed Processing and Manufacturing Plants," as it relates to general methods and procedures for measurements of radioactive material in air, radiological surveys of external radiation levels, and radiological surveys of surface contamination

- Regulatory Guide 8.25, "Calibration and Error Limits of Air Sampling Instruments for Total Volume of Air Sampled," as it relates to radiological surveys, air sampling, calibration of instruments, survey frequency, and data recording.

2.3.2 NRC Draft Documents

The following NRC draft documents provide additional guidance to the applicant in meeting the environmental monitoring requirements identified in Sections 2.1 and 2.2 of this document:

- Draft Regulatory Guide Task ES 401-4, "Onsite Meteorological Measurement Program for Uranium Recovery Facilities - Data Acquisition and Reporting," as it relates to general objectives and guidelines for meteorological measurements, parameters measured, data recording, data reduction, and instrument accuracy

- Draft "Technical Position Paper - Environmental Monitoring of Low-Level Radioactive Waste Disposal Facilities," (NRC 1988) as it relates to staff technical positions on elements appropriate to an environmental monitoring program at LLWDFs

- Draft NUREG-1293, Quality Assurance Guidance for Low-Level Radioactive Waste Disposal Facility (Pittiglio 1987), as it relates to the implementation of quality assurance for environmental monitoring programs at LLWDFs.

2.4 INDUSTRY STANDARDS AND OTHER GUIDANCE

A number of industry standards and other guidance documents are available to the applicant for guidance in meeting regulatory requirements for environmental monitoring programs at LLWDFs. Some of these documents are listed in the following two subsections, while more definitive applications of each are provided in the specific environmental monitoring sections of this document that follow: 3.0 (preoperational), 4.0 (operational), and 5.0 (postoperational).

2.4.1 Industry Standards

The following industry standards provide specific guidance with respect to sampling and measurement techniques for environmental monitoring programs for LLWDFs:

- American National Standards Institute, ANSI N13.1-1969, Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities, as it relates to the implementation of radiation monitoring equipment criteria and general guidance on sampling airborne radioactive material

- American National Standards Institute, ANSI N323-1969, Radiation Protection Instrumentation Test and Calibration, as it relates to guidance on the calibration of instruments

- American National Standards Institute, ANSI N545-1975, Performance, Testing, and Procedural Specifications for Thermoluminescent Dosimetry, as it relates to the application of thermoluminescent dosimeters

- American National Standards Institute/American Nuclear Society, ANSI/ANS 3.1-1978, Selection and Training of Nuclear Power Plant Personnel, as it relates to general criteria for the selection, qualifications, responsibilities, and training of personnel in operating and support organizations appropriate for the safe and efficient environmental monitoring operations at LLWDFs.

2.4.2 General Guidance Documents

The following documents provide additional guidance with respect to establishing and implementing environmental monitoring programs for LLWDFs:

- National Council on Radiation Protection and Measurements (NCRP), Instrumentation and Monitoring Methods for Radiation Protection, NCRP Report 57, as it relates to radiological survey methods, surface and airborne radioactivity measurements, and survey instruments

- National Council on Radiation Protection and Measurements, A Handbook of Radioactivity Measurements Procedures, NCRP Report 58, as it relates to field and laboratory instruments for the measurement of radioactivity, methods for measuring radioactivity, techniques for the preparation of samples, statistical treatment of data, and quality assurance of measurement accuracy and precision

- National Council on Radiation Protection and Measurements, Environmental Radiation Measurements, NCRP Report 50, as it relates to requirements for monitoring and surveillance programs, *in situ* measurements, sample collection and preparation for laboratory analysis, and laboratory measurements

- U.S. Department of Energy, Environmental Measurements Laboratory, EML Procedures Manual (Harley 1986; formerly HASL-300), as it relates to sampling techniques, field measurements, analytical laboratory equipment, radiochemistry practices, and counting statistics

- U.S. Environmental Protection Agency, Manual of Ground-Water Sampling Procedures (Scalf et al. 1981) as it relates to methods for installing ground-water sampling stations and ground-water sampling procedures

- U.S. Environmental Protection Agency, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, as it relates to methods and procedures for sampling ground water

- U.S. Environmental Protection Agency, Upgrading Environmental Radiation Data, EPA 520/1-80-012, as it relates to statistical methods for radiation data interpretation, reporting of radiation measurement data, and quality assurance for environmental monitoring programs

- U.S. Department of Energy, Low-Level Radioactive Waste Management Handbook Series, DOE/LLW-13Tg (Sedlet and Wynveen 1983), as it relates to the general principles of environmental monitoring for LLWDFs

- U.S. Nuclear Regulatory Commission, "Environmental Surveillance Programs," addendum to NUREG/CR-0570 (Denham et al. 1981), as it relates to environmental monitoring and surveillance programs for LLWDFs.

2.5 REFERENCES

American National Standards Institute (ANSI). 1969. Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities. ANSI 13.1-1969, American National Standards Institute, New York, New York.

American National Standards Institute (ANSI). 1969. Radiation Protection Instrumentation Test and Calibration. ANSI N323-1969, American National Standards Institute, New York, New York.

American National Standards Institute (ANSI). 1975. Performance, Testing, and Procedural Specifications for Thermoluminescent Dosimetry: Environmental Applications. ANSI N545-1975, American National Standards Institute, Inc., New York, New York.

American National Standards Institute (ANSI). 1978. Selection and Training of Nuclear Power Plant Personnel. ANSI/ANS 3.1-1978, American Nuclear Society, La Grange Park, Illinois.

Atomic Energy Act of 1954. Pub. Law 83-703, 42 U.S.C. 2021.

Denham, D. H., P. A. Eddy, K. A. Hawley, R. E. Jaquish, and J. P. Corley. 1981. Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground - Environmental Surveillance Programs. NUREG/CR-0570 Addendum, U.S. Nuclear Regulatory Commission, Washington, D.C.

Harley, J. H. 1986. EML Procedures Manual (revised annually). HASL-300, U.S. Department of Energy, New York, New York.

National Council on Radiation Protection and Measurements (NCRP). 1976. Environmental Radiation Measurements. NCRP Report 50, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

National Council on Radiation Protection and Measurements (NCRP). 1978. Instrumentation and Monitoring Methods for Radiation Protection. NCRP Report 57, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

National Council on Radiation Protection and Measurements (NCRP). 1985. A Handbook of Radioactivity Measurements Procedures. NCRP Report 58, 2nd ed., National Council on Radiation Protection and Measurements, Bethesda, Maryland

Pittiglio, C. L., Jr. 1987 (Draft). Quality Assurance Guidance for Low-Level Radioactive Waste Disposal Facility. NUREG-1293, U.S. Nuclear Regulatory Commission, Washington, D.C.

Regulatory Guide 4.5, Rev. 1 (1974); "Measurements of Radionuclides in the Environment, Sampling and Analysis of Plutonium in Soil." U.S. Atomic Energy Commission (AEC), Directorate Office of Regulatory Standards, Washington, D.C.

Regulatory Guide 4.13, Rev. 1 (1977); "Performance, Testing, and Procedural Specifications for Thermoluminescence Dosimetry: Environmental Applications." U.S. Nuclear Regulatory Commission (NRC), Office of Standards Development, Washington, D.C.

Regulatory Guide 4.15, Rev. 1 (1979); "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment." U.S. Nuclear Regulatory Commission (NRC), Office of Standards Development, Washington, D.C.

Regulatory Guide 8.2 (1973); "Guide for Administrative Practices in Radiation Monitoring." U.S. Atomic Energy Commission (AEC), Directorate of Regulatory Standards, Washington, D.C.

Regulatory Guide 8.6 (1973); "Standard Test Procedure for Geiger-Müller Counters." U.S. Atomic Energy Commission (AEC), Directorate of Regulatory Standards, Washington, D.C.

Regulatory Guide 8.21 (1979); "Health Physics Surveys for Byproduct Material at NRC Licensed Processing and Manufacturing Plants." U.S. Nuclear Regulatory Commission (NRC). Office of Standards Development, Washington, D.C.

Regulatory Guide 8.25 (1980); "Calibration and Error Limits of Air Sampling Instruments for Total Volume of Air Sampled." U.S. Nuclear Regulatory Commission (NRC), Office of Standards Development, Washington, D.C.

Regulatory Guide Task ES 401-4 (Draft 1985); "Onsite Meteorological Measurement Program for Uranium Recovery Facilities - Data Acquisition and Reporting." U.S. Nuclear Regulatory Commission (NRC), Office of Nuclear Regulatory Research, Washington, D.C.

Scalf, M. R., F. McNabb, J. D. William, R. L. Costy, and J. Fryberger. 1981. Manual of Ground-Water Quality Sampling Procedures. EPA-600/2-81-160, U.S. Environmental Protection Agency, Ada, Oklahoma.

Sedlet, J., and R. A. Wynveen. 1983. Low-Level Radioactive Waste Management Handbook Series - Environmental Monitoring for Low-Level Waste-Disposal Sites. DOE/LLW-13Tg, U.S. Department of Energy, Idaho Falls, Idaho.

U.S. Code of Federal Regulations, Title 10, Part 20 (10 CFR 20); "Standards for Protection Against Radiation."

U.S. Code of Federal Regulations, Title 10, Part 61 (10 CFR 61); "Licensing Requirements for Land Disposal of Radioactive Waste.

U.S. Code of Federal Regulations, Title 40, Part 61 (40 CFR 61); "Regulations on National Emission Standards for Hazardous Air Pollutants."

U.S. Environmental Protection Agency (EPA). 1980. Upgrading Environmental Radiation Data. EPA 520/1-80-012, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document. EPA/OSWER 9950.1, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988 (Draft). "Technical Position Paper - Environmental Monitoring of Low-Level Radioactive Waste Disposal Facilities." U.S. Nuclear Regulatory Commission, Division of Low-Level Waste Management and Decommissioning, Washington, D.C.

3.0 PREOPERATIONAL ENVIRONMENTAL MONITORING

.reoperational environmental monitoring programs must be designed to flow smoothly into the subsequent phases. The design of these programs will be crucial to the success of the operational and postoperational phases. Methods and frequency of sampling and location of sampling will vary between arid and humid sites because of geography, hydrology, and climate; however, the requirements and the objectives will remain the same for the three disposal alternatives considered in this document.

3.1 PROGRAM REQUIREMENTS AND OBJECTIVES

The environmental monitoring program requirements for low-level radioactive waste disposal facilities (LLWDFs) are provided in 10 CFR 61.53. The primary objective of a LLWDF preoperational environmental monitoring program is to determine existing radiation levels, radionuclide concentrations, and existing levels of selected nonradiological constituents in the site environs prior to any waste-handling operations. This section presents the requirements and supporting objectives, a discussion of these requirements and objectives, and a summary of recommendations to be used by the U.S. Nuclear Regulatory Commission (NRC) review staff.

3.1.1 Requirements

The environmental monitoring program requirements for LLWDFs are provided in 10 CFR 61.53(a), as quoted, in part, below:

> At the time a license application is submitted, the applicant shall have conducted a preoperational environmental monitoring program to provide basic environmental data on the disposal site characteristics. . . .

In addition, 61.53(b) requires the licensee to ". . . have plans for taking corrective measures if migration of radionuclides would indicate that the Performance Objectives of Subpart C [10 CFR 61.40 through 61.44] may not be met," a requirement that can only be evaluated based on [illegible] existence of environmental data prior to the start of site waste-han[illegible] operations.

3.1.2 Objectives

[illegible] noted above, the regula[illegible]ns [10 CFR 61.53(a)] require that the appl[illegible]t [illegible]ide evidence of having conducted a preoperational environmental moni[illegible] [illegible]ogra[illegible] [illegible]hat provides ". . . basic environmental data . . ." on the [illegible] [illegible]r a min[illegible] period of one year prior to the license application. Hence [illegible]imary ob[illegible] of the preoperational environmental monitoring prog[illegible] [illegible]isting radiological and selected nonradiological cond[illegible] [illegible]irons prior to any waste disposal operations. Othe[illegible] [illegible] are noted in Section 3.4 of the alternative methods [illegible] [illegible]ct 1985; Miller and Bennett 1985; Warriner and

Bennett 1985) and in Section 2 of the draft "Technical Position Paper" (NRC 1988). These include the need to:

- determine natural and manmade radioactivity patterns on the site
- determine background radiation levels and radionuclide concentrations on the site
- determine existing levels of selected nonradiological constituents on the site, especially those that could affect the future transport of radionuclides
- characterize the site and possible processes that could affect future releases
- further define potential critical pathways for radionuclide migration and, hence, environmental media to be sampled to evaluate these pathways
- establish a data base of environmental background values, that provide a statistical basis for evaluating future environmental performance
- provide a data base useful in the selection and verification of site models for the environmental transfer of potential site contaminants
- provide a method for determining when corrective actions are necessary; i.e., a plan of action to be implemented when the values of one or more parameters exceed a specified action level.

3.1.3 Discussion

Besides the objectives noted above, some of the investigations conducted as part of the site characterization effort may be useful for establishing and evaluating the data observed from the preoperational environmental monitoring program. These include investigation of the following:

- natural and artificial features of the site that could affect radionuclide dispersion and reconcentration in the environment, such as geological, hydrological, and meteorological conditions, and the presence of biological species
- the utilization of the environment for agriculture, water and food supplies, industry, habitation, recreation
- the distribution of the population according to age, sex, dietary, occupational, domestic, and recreational habits
- the establishment of locations for monitoring and sources of supply of environmental samples.

Other NRC guidance on objectives for preoperational environmental monitoring programs at LLWDFs has been provided in the NRC Task Group report (NRC 1975) and an environmental surveillance addendum (Denham et al. 1981). More recently, the U.S. Department of Energy (DOE) has issued a Low-Level Radioactive Waste Management Handbook (Sedlet and Wynveen 1983) with environmental monitoring program objectives. These sources also note that the preoperational program may serve to train staff and to test the equipment, instruments, and organization of the proposed operational environmental monitoring program.

As noted above, the primary purpose of the preoperational environmental monitoring programs for LLWDFs is to fully evaluate existing environmental conditions before any waste-handling operations are begun. Hence, the preoperational environmental monitoring programs should consist principally of collecting data to document the radiological and selected nonradiological (see Section 3.1.4, p. 3.5) constituent levels on the site and surrounding environs, as well as to gather information on the demography, ecology, and land and water use patterns in the area. Some of this information may be available as a result of the collection of geohydrological, meteorological, and climatological data during the site characterization and selection process. The NRC reviewer(s), in determining the acceptability of the preoperational program, must determine whether the applicant has chosen to use any of these data and to determine if their source and validity (applicability) have been adequately documented.

3.1.4 Recommendations

The reviewer(s) must determine the acceptability of the preoperational environmental monitoring program by verifying that the program meets the requirements of 10 CFR 61.53(a). Components of the described preoperational environmental monitoring program would normally include both quality (e.g., concentrations or levels) and quantity (e.g., flow rates, volumes, directions) for meteorological (e.g., air and precipitation), hydrological (e.g. of saturated zone, vadose zone, and surface waters), geological (e.g., soil and sediment), and biological (e.g., vegetation and other biota) parameters as well as for direct radiation monitoring. The description of the monitoring program should also show that special program features have been considered, such as analyses for specific radionuclides or other contaminants, because of pre-existing site-specific parameters or conditions. The applicant's preoperational environmental monitoring program should identify and include, as a minimum, discussion of the following elements, which are further summarized in the review criteria checklist provided in Table 3.1:

- determination of existing background radiation and radionuclide levels
- an estimate of the variability of existing radiation and radionuclide levels
- determination of existing chemical (nonradiological) parameters that may affect the transport or migration of radionuclides
- identification of potential critical pathways to humans, based on site-specific waste disposal processes.

TABLE 3.1. Preoperational Environmental Monitoring Program Requirements - Review Criteria Checklist

Subject	Review Criteria
Bases	10 CFR 61.53(a)
Baseline data:	
Radiological	Natural emitters (U, Th, K); fallout (Sr, Cs, Pu); other nearby nuclear facility (e.g., reactors and fuel fabrication plants) emissions; and mobile nuclides (e.g., tritium, Ru, and Tc) expected to be included in site disposals
Nonradiological	Major inorganic constituents, including important trace elements and dissolved gases; major organic constituents, dissolved and total organic carbon, total organic halogens, fecal coliforms and streptococci; pH, total dissolved solids; turbidity; temperature
Corrective action plan	10 CFR 61.12(l); 10 CFR 61.53(b)
Environmental variability evaluation	10 CFR 61.53(a); Minimum program duration, 1 yr; must sample at least seasonally
Pathways identification	Inclusion of pathway analysis, per 10 CFR 61.13(a), using standard models (e.g., AIRDOS-EPA, MAXI, etc.)

In particular, the preoperational environmental monitoring program should include monitoring of each of the following site-specific parameters:

- radiation measurements and radionuclide concentrations including such radiological parameters as

  (a) ambient radiation levels (taken at 1 m above the ground surface) at a number of locations within 10 km of the site as well as in the nearest residential community or city of 10,000 or more population within 50 km of the site

(b) concentrations of the major naturally occurring radionuclides (e.g., uranium, thorium, potassium) in applicable environmental media (e.g., air, water, soil, and biota)

(c) concentrations of the major fallout radionuclides (e.g., strontium-90, cesium-137, and plutonium-239) or appropriate radionuclides that could be included as emissions from other nearby (within 50 km) nuclear installations in applicable environmental media (e.g., air, water, soil, and biota)

(d) concentrations of the radionuclides expected to be included in disposed waste, especially those that could be considered mobile in the environment (e.g., tritium, technetium, and ruthenium)

- selected nonradiological constituents that might influence radionuclide transport, including parameters such as

  (a) concentrations of major inorganic constituents (including important trace elements) and dissolved gases

  (b) concentrations of major organic constituents, dissolved organic carbon, total organic carbon, total organic halogens, and water quality indicator organisms (e.g., fecal coliforms and fecal streptococci)

  (c) pH, oxidation/reduction conditions, total dissolved solids, specific conductance, alkalinity, ionic strength, and density

  (d) turbidity, and the nature of colloidal-sized materials

  (e) temperature

Other components of the preoperational environmental monitoring program can be expected to include:

- evaluation of sampling and analytical methods (especially if applicant proposes to operate its own analytical laboratory)
- determination of relationships between <u>in situ</u> measurements and environmental concentrations
- arrangement of sampling agreements with nearby residents and businesses.

Table 3.1 is presented as a checklist for the NRC reviewer(s) to use to evaluate the acceptability of the applicant's discussion of preoperational monitoring program objectives.

3.2 MONITORING PROGRAM ADMINISTRATIVE ORGANIZATION

The administrative organization for the three disposal alternatives will be based on the same regulation. Differences will occur because of scope of operations at the site but not because of a choice among alternative disposal methods.

3.2.1 Requirements

The administrative organization responsible for the preoperational environmental monitoring program should be based on the requirements of 10 CFR 61.11(b).

3.2.2 Discussion

At the preoperational phase, the information requirements of 10 CFR 61.11(b) include the need for the application to identify and describe:

- the organizational structure of the applicant, both offsite and onsite, including lines of authority and assignments of responsibility
- the technical qualifications, including training and experience, for personnel filling key positions in the organizational structure
- the applicant's personnel training program

3.2.3 Recommendations

The administrative organization responsible for the preoperational environmental monitoring program should include at least one health physics professional; a minimum of one health physics technician; and the authority of the health physics (radiation protection) staff to have direct access to higher level management (e.g., a vice-president) within the corporation that is responsible for the safe operation of the proposed disposal site. The NRC staff should further assess the information submitted by the applicant to ensure that the lines of authority, assignments of responsibility, and qualifications of the technical staff are clearly defined, and that the description of the staff training program includes appropriate detail for the radiological and nonradiological conditions expected at the site, as well as the fact that appropriate personnel are identified for the training. The administrative practices should be in accordance with 10 CFR 61.11(b) and consistent with Regulatory Guide 8.2.

Table 3.2 is a suggested checklist for use by the NRC staff to evaluate the acceptability of the applicant's administrative organization with respect to the preoperational environmental monitoring program

TABLE 3.2. Preoperational Administrative Organization - Review Criteria Checklist

Subject	Review Criteria
Bases	10 CFR 61.11(b); Reg. Guide 8.2
Lines of Authority	Rad Safety access to vice-president
Personnel qualifications	Health Physicist - 5 yr professional experience
Personnel training	Rad safety training planned at least annually; appropriate personnel (Health Physics technician, environmental monitors) included

3.3 EQUIPMENT, INSTRUMENTATION, AND FACILITIES

The three disposal alternatives will require similar equipment, instrumentation and facilities. Maintenance and storage may differ because of climatic conditions; however, the following subsections are equally applicable for sites using any one of the alternatives.

3.3.1 Requirements

The equipment used for sampling, the instrumentation used to measure levels or concentrations of material, and the facilities used to perform analyses, store samples, and house sampling equipment must meet applicable requirements for the licensing of a LLWDF. These requirements are defined in specific sections of the U.S. Code of Federal Regulations. At the preoperational stage, the requirements are identified in 10 CFR 61.12, "Specific Technical Information," items (k) and (l), as the procedures, instrumentation, facilities, and equipment to be used in the preoperational environmental monitoring program to provide the baseline data against which future site impacts will be evaluated.

The equipment, instrumentation, and facility requirements that pertain to environmental monitoring must be addressed in the license application. Basically, five media are to be sampled in the preoperational phase [e.g., 10 CFR 61.13(a)], and they include: 1) airborne particulates and gases, 2) ground water, 3) surface water and surface runoff, 4) soil and sediments, and 5) vegetation and other biota. The following is the type of information required to be presented in the license application:

- description of locations of monitoring stations (in the buffer zone, if applicable, in the disposal zone, and offsite), including the spatial distribution and sampling elevations, both for surface and subsurface monitoring devices

- specification of the type of samplers, detectors, and monitors, and specification of the sensitivity, range, and accuracy of the instrumentation used for performing field sampling and radiation surveys; based especially on the guidelines found in NRC Regulatory Guides and national concensus standards

- explanation of the criteria used for the design and installation of the various monitoring stations, which should include the basis for the locations chosen

- rationale for the field monitoring equipment used at the various monitoring installations, which should include the basis for choosing particular equipment, such as the sensitivity and range

- description of the method for control of samples during collection, transportation, and analysis, which should include labeling, storage, and accountability of the samples

- description of the laboratory that will be processing the samples and performing the analyses; the basis for choice of laboratory should include accreditation and/or participation in U.S. Environmental Protection Agency (EPA) or other recognized interlaboratory cross-check programs

- listing and description of the analytical equipment and instrumentation, and the procedures for their operation, including a description of the accuracy, sensitivity, and range of the instrumentation used in the laboratory, if the applicant plans to operate its own analytical laboratory

- description of the range, detection levels, and accuracy of the analytical procedures used in the laboratory, including the need for calibration and maintenance.

3.3.2 Discussion

Appropriate descriptions of the monitoring locations and equipment as well as the procedures for sample collection, transport, and analysis are an essential part of the information needed by the reviewer to ensure the production of quality data from environmental monitoring programs. Adequate preoperational environmental monitoring data can only be obtained in a minimum period of 1 year, or in such a time frame as to determine the variability in the radiological and nonradiological parameters, if the equipment, instrumentation, and facilities are capable of performing over the time period required. If equipment or instruments are not expected to last for the time period, reserve equipment or instruments must be available to replace field equipment or instruments that become inoperable.

Goals for the use of various instruments and facilities should include:

- an accurate estimation of the concentration of radiological and nonradiological contaminants for each of the sampling locations
- the ability to determine the concentrations of contaminants in a range that is within regulatory guidelines
- relevant sampling
- sampling of appropriate media
- an appropriate number of samples collected
- an appropriate choice of sampling locations
- an appropriate method of sampling
- samplers designed to collect appropriate samples
- an appropriate method of sample collection
- an appropriate method of analysis of collected samples.

3.3.3 Recommendations

Guidelines for acceptable field equipment and laboratory instruments are provided in Regulatory Guides 4.5, 4.6, 4.13, 8.6, 8.21, 8.25, and Regulatory Guide Task ES 401-4; in ANSI Standard N13.1-1969; and in publications of the DOE (Harley 1986; Corley et al. 1981), the EPA (1976, 1982), Regulatory Guide 4.13, and others (APHA 1977; NCRP 1985). Use of these documents will help the reviewer ensure that the applicant's sampling program complies with the intent of the license requirements outlined in Section 3.3.1 of this document.

Items that need to be addressed within each medium are as follows:

- Air--Both off gases and particulates, radiological and nonradiological, sampler design, and the appropriateness of the sample
- Ground Water--Primarily dissolved radiological and nonradiological constituents, sampler design, sample collection, and sample preservation
- Surface Water and Runoff--Both dissolved particles and particulates, radiological and nonradiological, sampling procedures, sample preservation, appropriateness of the sample, and adequate sensitivity of the analysis
- Sediment and Soil--Solids only for both radiological and nonradiological analyses; sampler design, spacing, sample appropriateness, and sample preservation

- Vegetation and Other Biota--Appropriateness of sample for constituents sought as well as relationship to potential human exposure, sample preservation, and analysis.

3.4 MONITORING PROGRAM IMPLEMENTATION

Although the choice of sites may differ for the application of each of the three disposal alternatives considered in this document, the preoperational monitoring programs are assumed to be identical. Hence, the ensuing subsections on requirements, discussion, and recommendations are equally applicable for sites using below-ground vaults, earth-mounded concrete bunkers, or augered-shaft disposal techniques.

The primary site differences are associated with the geology, hydrology and climatology rather than with the functional and operational disposal methods. As described in Section 1.5 of this document, an arid western site and a humid eastern site are assumed to represent the range of potential environmental conditions to be evaluated during the preoperational phase.

The arid site has summers marked by very low precipitation and high temperatures, resulting in soil moisture deficiencies and occasional periods of high winds accompanied by blowing soil. The depth to ground water can be 60 to 100 m, and the soil has moderate-to-high hydraulic conductivity, concomitant with a relatively long distance from the disposal site to the point of ground-water discharge into surface streams.

The humid site has a continental climate with widely ranging 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 in the north or by more moderate temperatures hovering around the freezing point and long rainy seasons in the south. The annual precipitation exceeds 100 cm, and the depth to ground water is only 10 to 15 m. Relatively short distances exist from the disposal site to the point of ground-water discharge into surface streams, and the soil has a low hydraulic conductivity.

3.4.1 Requirements

The regulations applicable to the review of a license application for a LLWDF with respect to the preoperational environmental monitoring program include the specific sections of 10 CFR 61 and 10 CFR 20 noted in Section 2.0 of this document. These regulations ensure protection of the general population from releases of radioactivity at LLWDF sites by defining the types of pathways to be analyzed [10 CFR 61.13(a)]; the duration of the monitoring program [10 CFR 61.53(a)] and location of sampling [10 CFR 61.12(1)]; and the sensitivity [10 CFR 61.13(a) and 10 CFR 20.106].

Pathways to be evaluated (i.e., samples/measurements to be made) - Subsection 10 CFR 61.13(a) stipulates that the pathways analyzed must include "air, soil, ground water, surface water, plant uptake, and exhumation by burrowing animals."

Duration of preoperational program - The last sentence of Subsection 10 CFR 61.53(a) specifies that for those characteristics subject to seasonal variation, "data must cover at least a twelve-month period."

Location of sampling - Subsection 10 CFR 61.12(l) specifies that the monitoring program "provide data to evaluate potential . . . impacts and the plan for taking corrective measures if migration of radionuclides is indicated."

Minimum sensitivity of sampling program - The last sentence in Subsection 10 CFR 61.13(a) specifies that the analyses must clearly demonstrate that the "exposure to humans from the release of radioactivity will not exceed the limits set forth in § 61.41;" similarly, 10 CFR 61.53(b) stipulates that the licensee have plans for taking corrective action if radionuclide migration from the site would indicate "that the performance objectives of Subpart C [specifically § 61.41] may not be met;" and 10 CFR 20.106 provides restrictions on the release of radioactive materials to unrestricted areas such that they "shall not exceed the concentrations specified in Appendix B, Table II." These requirements control the minimum sensitivity of the instruments or equipment used in the measurements.

3.4.2 Discussion

Clearly, the primary requirements for preoperational environmental monitoring programs for LLWDFs are that the preoperational monitoring programs: 1) be established for a minimum period of 1 year or for such duration to include the expected variability in radiological and nonradiological parameters, in the absence of a nuclear facility on that site or in the surrounding environs (i.e., within 6 to 10 km of the proposed site); and 2) include evaluation of the natural contaminants on the site, as well as those contaminants expected to be included in the wastes to be disposed at the site.

The preoperational environmental monitoring programs should be consistent with the draft "Technical Position Paper on Environmental Monitoring of Low-Level Waste Disposal Facilities" (NRC 1988). Additional guidance in choosing parameters for characterizing LLWDF sites is included in NUREG/CR-2700 (Lutton et al. 1982), the addendum to NUREG/CR-0570 (Denham et al. 1981) and in the appendices to this document.

The primary focus of the NRC review of the preoperational environmental monitoring program for LLWDFs is on the NRC-associated radiological requirements of 10 CFR 61. However, the review process should not overlook the other applicable federal, state, and local regulatory requirements. These other radiological and nonradiological parameter requirements are discussed in the chapter on operational monitoring requirements (Section 4.4.2 of the document). Preoperational monitoring plans should be designed to accommodate the need for adequate background data (constituent-specific) to be used as a basis for showing compliance with these other regulatory requirements.

3.4.3 Recommendations

The applicant's description of the preoperational environmental monitoring program objectives should include the program's duration, whether it will include both onsite and offsite monitoring locations, and the components of the preoperational program. The components to be evaluated will include parameters from the meteorological, hydrological, geological, and biological site characterization studies, as well as direct radiation measurements and environmental sampling from the preoperational environmental monitoring program. Recommended NRC review criteria for each of the site characterization and direct radiation components include the following:

- Meteorological information provided should include where the site meteorological data is to be obtained and whether it was used in establishing the location of sampling stations, especially for air, soil and vegetation collection.
- Hydrological information provided should include surface as well as subsurface hydrological parameters, including flow directions and rates, as the basis for sampling locations and sampling frequencies.
- Geological information provided should include an evaluation of unique geographic or geologic features at the proposed site that could modify the data to be obtained, especially from the presence or absence of pockets of naturally occurring radionuclides that could later confound observed radiation levels or radionuclide concentrations during the operational or postoperational periods of site activities.
- Biological information provided should include a consideration of at least the local game species important to hunters or trappers, especially those burrowing animals or game birds that could be in the direct-dose pathway to humans; vegetation should be considered for root intrusion or penetration into the subsequently disposed waste or to be indicative of surface contamination from deposition of airborne gases, vapors (e.g., tritiated water vapor, or carbon-14 labeled methane or carbon dioxide) or particulates (i.e., more than one species of both flora and fauna, even during the preoperational period).
- Direct radiation measurement locations and distribution should be based on the proposed locations of waste handling and emplacement activities and the location and distribution of the local population that could be exposed to external radiation emanating from the site.

Each proposed preoperational environmental monitoring program should be tailored to site-specific conditions. The number and frequency of sampling and/or measurements should be based on the need to meet the requirements noted earlier in this section, especially with regard to establishing an adequate environmental data base against which future monitoring data will be compared. Selection of the analyses to be performed should be based on naturally occurring radionuclides in typical site environmental media; weapons-testing fallout or appropriate radionuclides that could be included as emissions from other nearby nuclear installations; and the expected radionuclide composition of the waste to be disposed.

Table 3.3 is suggested as a checklist for the NRC reviewer(s) to use in the evaluation of the acceptability of the applicant's description of the preoperational environmental monitoring program.

3.5 DATA RECORDING AND STATISTICAL ANALYSES

Data recording and statistical analysis will be identical for the three alternatives for LLWDFs.

3.5.1 Requirements

Although there are no regulatory requirements for data recording and statistical analysis, the following principles define good monitoring practices for a LLWDF preoperational monitoring program:

- data recorded in appropriate units and expressed with an appropriate number of significant figures
- unambiguous overall estimates provided for the uncertainties associated with the measurements of radioactivity and radionuclide concentrations
- reported measurement results include the descriptive statistics (e.g., measured or calculated values, sample size, mean, standard deviation, overall uncertainty and confidence interval for the mean)
- an estimate of the statistical validity of the sampling program provided by the applicant
- statistical treatment of data in accordance with the statistical treatment practices presented in the following documents: NCRP 1985, Watson 1980, and NRC 1975
- descriptions and rationale associated with these practices are in accordance with the following documents: Watson 1980, EPA 1972, and NRC 1975.

3.5.2 Discussion

Consistent data recording and statistical analyses are essential for the production of quality results from the environmental monitoring and surveillance programs associated with a LLWDF. In addition to the statistical guidance provided in NCRP (1985), NRC (1975), and EPA (Watson 1981; EPA 1972) (see Section 3.5.1), more in-depth discussions of statistical methods and principles can be found in Gilbert (1987), Hollander and Wolfe (1973), and Winer (1971). The overall goals of such environmental monitoring and surveillance data analysis practices should be:

TABLE 3.3. Preoperational Environmental Monitoring Program Implementation - Review Criteria Checklist

Subject	Review Criteria
Program description	10 CFR 61.12(l); 10 CFR 61.53(a) and (c); and NRC "Technical Position Paper - Environmental Monitoring"
Program duration	10 CFR 61.53(a); establishes minimum program duration of 1 yr
Appropriate sampling media	10 CFR 61.13(a); addresses at least air, soil, ground water and surface water, plants, and burrowing animals
Direct radiation	Includes measurement and analysis of direct radiation, a potential critical pathway
Appropriate sampling locations	10 CFR 61.12(l); provides adequate data to evaluate need for corrective measures
Background/control locations	Identifies at least one background location per medium/measurement
Adequate detection sensitivities	10 CFR 20.106; applies to Table II, Appendix B concentration values
Critical nuclides included	Evaluates critical nuclides, based on pathway analysis using standard models (e.g., AIRDOS-EPA, MAXI, etc.)
Measurement frequency	10 CFR 61.53(a); addresses temporal and spatial variability
Special samples/analyses	Includes special samples or analyses; e.g., precipitation for humid sites, certain analyses for pre-existing site-specific parameters
Administrative action levels	10 CFR 20.106; 10 CFR 61.12(l); use of concentration limits (e.g., Table II, Appendix B of 10 CFR 20), control charts, statistical analyses (see Section 3.5) to establish corrective action levels
Appropriate sampling/measurement methods	Reg. Guides 4.1, 4.5 (AEC), 4.6, 4.13, 8.6, 8.25, and ES 401-4

- to estimate concentrations of radiological and selected nonradiological constituents at each sampling or measurement point for each sampling or measurement time, and to estimate accuracy and precision

- to compare the estimated concentrations at each sampling or measurement point to previous concentration estimates at that point to identify changes or inconsistencies in observed levels

- to compare the concentrations at each sampling or measurement point to established limit(s) or guides for those constituents

- to compare concentrations at single sampling or measurement points or groups of points to those at control or other points and evaluate the reliability of those comparisons.

Mean Value Analyses

The statistical techniques used to calculate the concentration estimates and their corresponding measures of reliability and to compare radionuclide data between stations and times should be designed to accommodate the characteristics of effluent and environmental data. These characteristics include a time series of data with skewed distributions (usually lognormal), a high degree of variability, and often large amounts of missing data and readings that are below the detection limit of the sample analysis technique. Proper sampling, sample-handling, and data-management techniques must be designed into the environmental monitoring and surveillance practices to reduce program related variability as much as possible.

An adequately designed environmental monitoring and surveillance program should consider sources of variability in data such as those listed in Table 3.4. These sources of variability can be divided into three types: environmental, sampling, and recording. Adequate data analysis practices should consider the relevancy of the variability source with respect to the actual conditions at the sampling or measurement point. The analysis should also consider the site's ability to modify that source of variability in comparison with the impact that source of variability has on the data.

Adequate data analysis practices should involve an estimate of the levels of accuracy and precision required for the data, based on (if possible) previous site monitoring and surveillance experience. The data analysis and handling strategies should be designed with these estimates of the level of accuracy and precision in mind. Also, plans should provide for periodic (or after significant modification to site conditions) re-evaluation of these strategies to determine if they are adequate for the current site conditions.

TABLE 3.4. Sources of Data Variability (from Corley et al. 1981)

Type	Source	Examples
Environmental	Space	Distance from emission sources, elevation, heterogeneous dispersion of material
	Time	Variations in rates of emissions, variation in rates of dispersion
	Space x time	Nonstationary differences between sampling stations over time
Sampling	Sample collection	Nonrepresentative sampling, inconsistent sampling techniques, sampling equipment failure
	Sample handling	Chemical reactions, non-uniform storage conditions, container effects
	Sample processing	Volume or weight measurement errors, insufficient sample mixing, nonrepresentative subsampling
	Measurement	Calibration errors, instrument errors, readout and calculation errors
	Cross-contamination	Cleanliness of containers and work areas, sealing of containers for transport, surface contamination from transport, separation of high- and low-activity samples, decontamination practices
Recording	Data recording and transfer	Errors in data entry, errors in transfer of data from lab books to computer files

A measure of central tendency is usually needed to summarize the information in a data set (e.g., in the calculation of a yearly average concentration). In addition, an estimate of precision is required for that summary statistic. Assumptions about the underlying data distribution are inherent in the calculation of most statistical parameters; therefore, an environmental monitoring and surveillance program with adequate data analysis practices should consider the distribution of the radionuclide concentration data in order to ensure that the calculated parameters will be valid.

Appropriate measures of central tendency should be reflected in the data analysis practices included in an environmental monitoring and surveillance plan. The appropriate measure of central tendency depends on the characteristics of the radionuclide concentration data collected. For normally distributed data with only a small number of extreme or less-than-detectable values, the arithmetic mean is the appropriate estimator of central tendency. When a normally distributed data set contains large numbers of extreme values or concentrations below the analytical detection limits, the median, which is less sensitive to extreme values than the mean, should be used to summarize the data. Trimmed means (arithmetic means calculated while excluding some percentage of the upper and lower data values) can also be appropriate in these cases, though caution should be used so that rejected information does not introduce bias into the mean values so calculated.

Dispersion in normally distributed data, without large numbers of outliers and less-than-detectable values, should be represented as a variance, a standard deviation, a standard error, or a confidence interval. Again, data should be transformed, if necessary, to approximate a normal distribution.

For data with substantial numbers of extreme values, other measures should be used to estimate the dispersion around the central value. The full range of data values, or the interquartile range (the range of data between the 25th and 75th percentiles), and the median absolute deviation (the median of the differences between each data point and the indicator of central tendency) are also acceptable measures (Gilbert and Kinnison 1981).

The calculated mean from multiple measurements is used as the best estimate of the population mean and, hence, the true value (in the absence of bias). Because of the associated statistical fluctuations about the calculated mean, it may not be exactly equal to the true population mean. The confidence interval is the range of possible values on either side of the calculated mean, within which the true population mean can be expected to fall. Confidence limits are numerical values at the limits of this range. The true population mean can be expected to lie within the confidence limits with a given probability. This probability, usually expressed as a percentage, is called the confidence coefficient. Alternatively, the confidence coefficient can be considered to be the probability that the confidence interval will include the true population mean.

Extreme Value Analyses

Monitoring programs often include measurement of extremely low concentrations of radionuclides, below the detection limit of the counting instruments. Data sets with large numbers of less-than-detectable values need special consideration in the statistical analyses. Less-than-detectable data will produce numerical measurements with values below the detection limit and sometimes as impossible negative values. All of the actual values, including those that are negative, should be included in the statistical analyses. Practices such as assigning a zero, the detection limit value, or some in-between value to the below-detectable data point, or discarding those data points can severely bias the resulting parameter estimates and should be avoided.

Adequate data analysis practices should involve the comparison of each data point to previous data to determine whether the point is an outlier or true data to be included in the data set. An outlier is defined as an abnormally high or low data value. Outliers can represent true extreme values or can indicate malfunctions or failures in sampling equipment or variability in sample quality. When outliers are identified, a decision must be made whether to include those numbers in estimates of radionuclide concentrations or in comparisons between data sets. Most often what appear at first to be outliers turn out to be data transcription errors.

The presence of outliers can, however, severely affect the value of the estimated mean or the outcome of statistical comparisons. When outliers that are not attributable to errors are contained in the data set, estimators and statistical tests should be computed with and without the outliers to see if the results of the two calculations are markedly different. If the results differ substantially because of outliers in the data, then both results should be reported.

Measurement Precision

Often, calculations involving measured values result in numbers with more decimal places than were in the original measurements and give an erroneous impression of the precision and accuracy of results. The number of significant figures in reported data should reflect the precision in the measured values. A larger number of significant figures may be carried during the calculations to ensure computational accuracy.

The number of significant figures reported for raw data should reflect the true precision of the measurement technique. When measurements are multiplied or divided, the number of significant figures in the product or quotient should not exceed that of the least precise measurement used in the calculations. When measurements are added or subtracted, the recorded precision of the result should not exceed that of the least precise measurement.

A common practice in the monitoring of radionuclide concentrations is to measure the activity of the parent nuclide and calculate the amount of the decay products present from the known physical relationships. As an alternative, the concentrations of parent nuclides may be calculated from the measurement of the decay products. These calculations are relatively straightforward when the parent and decay products are at equilibrium, and in the absence of contrary data. Corrections should be made for calculations performed during the transitory period before equilibrium is reached. Correct estimation of the amount of the decay product (or parent) material present requires definite knowledge of the difference between the time of measurement and the time of the initiation of parent decay. The recorded accuracy and precision of the calculated radionuclide concentrations should not exceed that of the original measured concentration. Uncertainties in the length of time between measurement and the initiation of parent decay should be reported and incorporated into the precision estimates for the calculated concentrations.

3.5.3 Recommendations

The good-practice principles address the three basic issues that a reviewer must be sure are covered regarding the data recording and statistical analyses associated with the preoperational environmental monitoring program. These three basic issues are: 1) the recording of data in the proper units and with the correct implied accuracy (i.e., significant figures), 2) the estimating of the uncertainties associated with the data, and 3) the inclusion of the necessary descriptive statistics. However, refinements and additions to these basic requirements were incorporated into the Standard Review Plan for Preoperational Environmental Monitoring (NRC 1987). These refinements and additions are listed below:

- Plans for estimating level of accuracy must include the analyzing of blanks and spiked pseudosamples and for comparing the results with the known concentrations of these samples.
- Plans must incorporate the use of replicate samples to estimate precision for radiological analyses.
- Plans must provide for data to be entered into an appropriate data base promptly after analysis, with the inclusion of all outlier data. Outlier data should only be excluded if such data can be positively attributed to an analytical or sampling error.
- Plans must provide for the examination of data collected and the comparison to previous data to detect outliers (e.g., development of time plots of the data or control charts).
- Plans must include provisions to test data for normality where necessary (i.e., data sets containing more than 10 data points should be tested for normality).
- Plans must consider the incorporation of all the actual data values including the less-than-detectable values, even if such values are negative. Practices such as assigning a zero, the detection limit value, or some in-between value to the below-detectable data point,

or discarding those data points can severely bias the resulting parameter estimates and should be avoided where possible.

- Plans must incorporate the graphing of moving averages of the data, as soon as sufficient amounts of data (at least 10-15 data points) are acquired. These plots should be used to indicate overall trends in the data, which will aid in data interpretation as well as in detecting sampling or equipment errors.

- If parent-decay product relationship calculations are proposed for the calculation of radionuclide concentrations, provisions for reporting the uncertainties in the length of time between measurement and the initiation of parent decay and incorporating them into the precision estimates for the calculated concentrations must be addressed.

- Plans must not consider the use of single values to determine compliance with regulatory limits; instead additional sampling and/or measurement should be considered to ensure an accurate representation of the compliance status.

It is also recommended that a minimum acceptable confidence interval be established at the 95% level. Regulatory guidance does not specifically establish a minimum acceptable confidence interval, but the 95% level is the most commonly accepted level of confidence.

A review criteria checklist for data recording and statistical analyses is provided in Table 3.5.

TABLE 3.5. Data Recording and Statistical Analyses - Review Criteria Checklist

Subject	Review Criteria
Bases	Applicable portions of NCRP Report 58 (NCRP 1985), EPA 520/1-80-012 (Watson 1980), and NUREG-0475 (NRC 1975).
Units and significant figures	Activity (pCi, nCi), absorbed dose (mrad), dose equivalent (mrem); reflect accuracy by number of significant figures. Generally, environmental monitoring data do not warrant more than one or two significant figures.

TABLE 3.5 (cont)

Subject	Review Criteria
Estimates of uncertainty	Clear, complete, concise, uncertainty estimates for each reported value. Reported uncertainty based on as complete an assessment as possible [reference pages 6-7 through 6-24 of EPA 520/1-80-012 (Watson 1980)].
Descriptive statistics	Clear designation of where values are measured and where calculated; sample size; calculation of mean, deviation and overall uncertainty, and confidence interval for the mean. The 95% level is the minimum acceptable confidence interval.
Statistical validity of sampling	Clear discussion of the sources of data variability that were addressed in Table 3.5.
Estimating level of accuracy	Plans for analyzing blanks and spiked pseudosamples, and comparing results with known concentrations of these samples. (See also Table 3.8 in Quality Assurance and Control section.)
Precision estimates	Incorporation of replicate samples. (See also Table 3.8 in Quality Assurance and Control section.)
Outlier handling	Inclusion of all outlier data unless such data are positively attributable to an error; routine examination of data to detect outliers by means of time plots, control charts, etc.
Normality tests	Provisions for normality tests if data sets contain more than 10 data points.
Less-than-detectable values	Assignment of a value as realistic as possible. Avoid, where possible, assigning zero, the detection limit value or some in-between value, or discarding below-detectable values.
Trend and error detection analyses	Provisions for graphing of moving averages.

TABLE 3.5 (cont)

Subject	Review Criteria
Parent-decay product relationship	Provisions for reporting the uncertainties in the length of time between measurement and initiation of parent decay and incorporating it into calculated concentrations.
Single values and compliance	No single values to be used to determine compliance with regulatory limits.

3.6 DATA REPORTING

The reporting of preoperational environmental monitoring data to regulatory agencies is not required; however, it is part of the information to be submitted with the license application. Because a facility would not possess radioactive material during the preoperational phase, reporting requirements of 10 CFR 20 would not apply. The monitoring records produced during the preoperational phase must meet the requirements of 10 CFR 61 Subpart G, "Records Reports, Tests, and Inspections."

3.6.1 Requirements

The 10 CFR 61 records requirements that apply to preoperational environmental monitoring are from Subsection 61.80, as summarized below:

- Applicant shall maintain any records and make reports as may be required by the rules, regulations, and orders of the NRC.
- Records must be maintained through the period of operation and license (if issued) termination, and then transferred to the appropriate officials listed in the regulations as a condition of license termination, unless the NRC otherwise authorizes their disposition.
- Records may consist of the original or a reproduced copy or microfilm if this reproduced copy or microfilm is capable of producing copy that is clear and legible at the end of the required retention period.

3.6.2 Discussion and Recommendation

During the preoperational phase, the emphasis will be on obtaining background data. An essential aspect of this activity is maintaining these records as part of the permanent monitoring record of the site. If environmental permits require reporting during the preoperational phase, these requirements must also be met.

3.7 QUALITY ASSURANCE AND CONTROL

The quality assurance (QA) measures and quality control (QC) procedures should be adequate to ensure the accuracy and validity of the monitoring program. As used in this context, QA encompasses all those planned and systematic actions that are necessary to provide adequate confidence in the results of a monitoring program, and QC is composed of those QA actions that provide a means to control and measure the characteristics of measurement equipment and processes to established requirements; therefore, QA includes QC. These measures and procedures apply to the three disposal alternatives in all geographic areas.

3.7.1 Requirements

While there are no regulations *per se* with respect to quality assurance for LLWDF environmental monitoring programs, 10 CFR 61.12(j) requires the applicant provide "a description of the quality control program for the determination of natural disposal site characteristics . . ." including "audits and managerial controls. . . ." There are several NRC, EPA and other agency documents that provide QA guidance for nuclear facilities. Two in particular, Regulatory Guide 4.15 and draft NUREG-1293 (Pittiglio 1987), are used as the basis for the quality assurance programs at LLWDFs. Regulatory Guide 4.15 applies the concepts of quality assurance to environmental monitoring, noting especially that QA requirements should be consistent with the importance of the activity. The recent NRC draft (Pittiglio 1987), on the other hand, was prepared to provide "guidance to an applicant on development of a new low-level waste disposal facility in meeting the quality control (QC) requirements of 10 CFR 61.12," linking the QA/QC concepts directly to LLWDFs.

3.7.2 Discussion

The definition of QA and QC used in this document is from Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment." Any contractor or subcontractor performing monitoring for the applicant must implement a QA program incorporating the elements identified in this guide. These elements of the QA program are summarized below.

- Organizational Structure and Responsibilities of Managerial and Operational Personnel

  Includes the structure of the organization as it relates to the management and operation of the monitoring program, quality assurance policy and functions, and the authorities, duties, and responsibilities of the positions within this organization.

- Specification of Qualifications of Personnel

  Includes documentation of the qualifications of individuals performing radiological monitoring to carry out their assigned functions (e.g., as in a job description).

- Operating Procedures and Instructions

  Includes approved written procedures for all activities involved in carrying out the monitoring program.

- Records

  Specifies the records necessary to document the activities performed in the monitoring program.

  Includes the results of measurements of radioactive check sources, calibration sources, backgrounds, and blanks, which relate to laboratory counting systems.

  Includes the results of analysis of quality control samples such as analytical blanks, duplicates, interlaboratory cross-check samples and other quality control analyses, which relate to overall laboratory performance.

- Quality Control in Sampling (Including Packaging, Shipping, and Storage of Samples)

  Determines the accuracy of the devices used for sampling on a regularly scheduled basis. Makes adjustments as needed to bring performance of the devices within specified limits and record results of these calibrations.

  Designs operating procedures for grab samples to include steps that will ensure representative samples of the material and operating procedures for sampling, packaging, shipping, and storage of samples to maintain the integrity of the ample from time of collection to time of analysis.

- Quality Control in the Radioanalytical Laboratory

  Uses radionuclide standards that have been certified by NBS or standards that have been obtained from suppliers who participate in measurement assurance activities with NBS when such standards are available.

  Records the details of preparation of working standards from certified standard solutions. The working standard should be prepared in the same form as the unknown samples, or close approximation thereto.

  Checks efficiency calibrations periodically (typically monthly to yearly) with standard sources. Makes checks whenever the need is indicated, such as when a significant change in the measurement system is detected by routine measurements with a check source.

Determines background counting rate and the response of each radiation detection system to appropriate check sources on a scheduled basis for systems in routine use.

- Analysis of Quality Control Samples

  The fraction of the analytical effort needed for the analysis of quality control varies; however, for environmental laboratories, it is found that at least 5%, and typically 10%, of the analytical load should consist of quality control samples.

- Intralaboratory Analyses

  Analyzes replicate samples, usually duplicates, routinely.

  Includes known analytical blank samples to check for contamination from reagents and other sources. Submit spiked and blank samples for analysis to estimate the accuracy of the analytical results.

- Interlaboratory Analyses

  Splits analysis of effluent, environmental, and field samples, such as samples of milk, water, soil or sediment and vegetation, with one or more independent laboratories.

  Participates in the EPA's Environmental Radioactivity Laboratory Intercomparison Studies (Cross-Check) Program, or an equivalent program.

- Computational Checks

  Requires, in the computation of the concentration of radioactive materials, the independent verification of a substantial fraction of the results of the computation by a person other than the one performing the original computation.

- Review and Analysis of Data

  Develops procedures for review and analysis of data to cover examination of data from actual samples and from quality-control activities for reasonableness and consistency.

  Provides for investigation and correction of recognized deficiencies and for documentation of these actions.

• Audits

Arranges for planned and periodic audits by qualified individuals, who do not have direct responsibilities in the areas being audited, to verify implementation of the quality assurance program.

3.7.3 Recommendations

The QA requirements of Regulatory Guide 4.15 provide the basis for an adequate QA program for environmental monitoring at alternative LLWDF sites. The draft NUREG-1293 (Pittiglio 1987) specifically establishes QA/QC guidance for the ". . . site characterization [and, hence, the preoperational environmental monitoring program] activities necessary to meet the performance objectives of 10 CFR Part 61. . . ."

Other important references for use in developing the details of a QA program for environmental monitoring include Oakes et al. (1980), Kanipe (1977), and Chapter 5 of Quality Assurance For Environmental Monitoring Programs (Watson 1980).

The review criteria checklist for the QA portion of a license application is given in Table 3.6. Additional details on these criteria are provided in Regulatory Guide 4.15 and in draft NUREG-1293, Quality Assurance Guidance for Low-Level Radioactive Waste Disposal Facility (Pittiglio 1987).

In addition, the quality assurance activities that the applicant will employ in its environmental monitoring programs should be documented in a Quality Assurance Plan. The plan should define the procedures the applicant will employ to meet the criteria of 10 CFR 61.12(j), and to be consistent with the guidance in Regulatory Guide 4.15 and draft NUREG-1293 (Pittiglio 1987).

TABLE 3.6. Quality Assurance for LLWDF Environmental Monitoring Programs - Review Criteria Checklist

Subject	Review Criteria
Bases	10 CFR 61.12(j); Reg. Guide 4.15; NUREG-1293
Structure of organization	Defines management and operation of monitoring program, including QA policy and functions
Authorities	Identifies authorities, duties, and responsibilities down to first-line supervision

TABLE 3.6. (cont)

Subject	Review Criteria
Personnel qualifications	Specifies qualifications of individuals performing environmental monitoring functions
Written procedures	Includes approved procedures for all phases of monitoring program
Records	Establishes records to track and control all samples: field and inplant sample collection, including sample description; sample receipt and laboratory identification; sample preparation and radiochemical processing; and data reduction and verification
Supporting documentation	Includes documentation of calibration of radiation detectors, air samplers, and dosimetry systems; verification and qualifications of personnel; and results of audits
QC in sampling	Includes plans for documented procedures to address calibration, accuracy, representativeness, efficiencies, and reproducibility
QC in the laboratory (radionuclide reference standards)	Incorporates NBS-certified standards or standards suppliers who participate in measurement assurance programs with NBS; periodic (monthly to yearly) efficiency calibrations with standard sources
Performance checks	Includes routine (daily to weekly) determination of background and individual detector response to appropriate check sources
Analysis of QC samples	Provides for 5% to 10% of analytical load to consist of QC samples

TABLE 3.6. (cont)

Subject	Review Criteria
Interlaboratory analyses	Provides for routine analysis of replicate samples that are as homogeneous as possible (e.g., well-stirred or -mixed liquids; dried, ground, or screened solids); analysis of spiked and blank samples; analysis of environmental samples split with one or more independent laboratories, including participation in EPA's Environmental Radioactivity Laboratory Intercomparison Studies (Cross-Check) Program. See Table 3.7 in Data Recording and Statistical Analyses section.)
Computational checks	Provides for independent verification of substantial fraction of computations per guidelines in ANSI N413-1974
Review and analysis of data	Includes review and analysis of sample and QC data for reasonableness and consistency
Audits	Includes planned, periodic audits to verify implementation of QA program by qualified individuals who do not have direct responsibilities in the areas being audited

3.8 REFERENCES

American National Standards Institute (ANSI). 1969. Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities. ANSI N13.1-1969, American National Standards Institute, New York, New York.

American National Standards Institute (ANSI). 1974. Guidelines for Documentation of Digital Computer Programs and Automated Data Systems. ANSI N413-1974, American National Standards Institute, New York, New York.

American Public Health Association (APHA) Intersociety Committee. 1977. Methods of Air Sampling and Analysis, 2nd Edition. American Public Health Association, Washington D.C.

Bennett, R. D. 1985. Alternative Methods for Disposal of Low-Level Radioactive Wastes, Task 2e: Technical Requirements for Shaft Disposal of Low-Level Radioactive Waste. NUREG/CR-3774, Vol. 5, U.S. Nuclear Regulatory Commission, Washington, D.C.

Corley, J. P., D. H. Denham, R. E. Jaquish, D. E. Michels, A. R. Olsen, and D. A. Waite. 1981. A Guide For: Environmental Radiological Surveillance at U.S. Department of Energy Installations. DOE/EP-0023, U.S. Department of Energy, Washington, D.C.

Denham, D. H., P. A. Eddy, K. A. Hawley, R. E. Jaquish, and J. P. Corley. 1981. Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground - Environmental Surveillance Programs. NUREG/CR-0570 Addendum, U.S. Nuclear Regulatory Commission, Washington, D.C.

Gilbert, R. O. 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Company, New York, New York.

Gilbert, R. O., and R. R. Kinnison. 1981. "Statistical Methods for Estimating the Mean and Variance from Radionuclide Data Sets Containing Negative, Unreported or Less-Than Values." Health Phys. 40:377-390.

Harley, J. H. 1986. EML Procedures Manual (revised annually). HASL-300, U.S. Department of Energy, New York, New York.

Hollander, M., and D. A. Wolfe. 1973. Non-parametric Statistical Methods. John Wiley & Sons, New York, New York.

Kanipe, L. G. 1977. Handbook for Analytical Quality Control in Radioanalytical Laboratories. EPA-600/7-77-088, U.S. Environmental Protection Agency, Washington D.C.

Lutton, R. J., P. G. Malone, R. B. Meade, and D. M. Patrick. 1982. Parameters for Characterizing Sites for Disposal of Low-Level Radioactive Waste. NUREG/CR-2700, U.S. Nuclear Regulatory Commission, Washington, D.C.

Miller, W. O., and R. D. Bennett. 1985. Alternative Methods for Disposal of Low-Level Radioactive Wastes, Task 2c: Technical Requirements for Earth Mounded Concrete Bunker Disposal of Low-Level Radioactive Waste. NUREG/CR-3774, Vol. 4, U.S. Nuclear Regulatory Commission, Washington, D.C.

National Council on Radiation Protection and Measurements (NCRP). 1985. A Handbook of Radioactivity Measurements Procedures. NCRP Report 58, 2nd ed., National Council on Radiation Protection and Measurements, Bethesda, Maryland.

Oakes, W., K. W. Shanks, and J. S. Eldridge. 1980. "Quality Assurance Applied to Environmental Radiological Surveillance." Nuclear Safety 21(2):217-226.

Pittiglio, C. L., Jr. 1987 (Draft). Quality Assurance Guidance for Low Level Radioactive Waste Disposal Facility. NUREG-1293, U.S. Nuclear Regulatory Commission, Washington, D.C.

Regulatory Guide 4.1 (1975); "Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants." U.S. Nuclear Regulatory Commission (NRC), Office of Standards Development, Washington, D.C.

Regulatory Guide 4.5, Rev. 1 (1974); "Measurements of Radionuclides in the Environment, Sampling and Analysis of Plutonium in Soil." U.S. Atomic Energy Commission (AEC), Directorate of Regulatory Standards, Washington, D.C.

Regulatory Guide 4.6 (1974); "Measurements of Radionuclides in the Environment, Strontium-89 and Strontium-90 Analyses. U.S. Atomic Energy Commission (AEC), Directorate of Regulatory Standards, Washington, D.C.

Regulatory Guide 4.13, Rev. 1 (1977); "Performance, Testing, and Procedural Specifications for Thermoluminescence Dosimetry: Environmental Applications." U.S. Nuclear Regulatory Commission, Office of Standards Development, Washington, D.C.

Regulatory Guide 4.15, Rev. 1 (1979); "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment." U.S. Nuclear Regulatory Commission (NRC), Office of Standards Development, Washington, D.C.

Regulatory Guide 8.2; (1973) "Guide for Administrative Practices in Radiation Monitoring." U.S. Atomic Energy Commission (AEC), Directorate of Regulatory Standards, Washington, D.C.

Regulatory Guide 8.6 (1973); "Standard Test Procedure for Geiger-Müller Counters." U.S. Atomic Energy Commission (AEC), Directorate of Regulatory Standards, Washington, D.C.

Regulatory Guide 8.21, (1979); "Health Physics Surveys for Byproduct Material at NRC Licensed Processing and Manufacturing Plants." U.S. Nuclear Regulatory Commission (NRC), Office of Standards Development, Washington, D.C.

Regulatory Guide 8.25; (1980); "Calibration and Error Limits of Air Sampling Instruments for Total Volume of Air Sampled." U.S. Nuclear Regulatory Commission (NRC), Office of Standards Development, Washington, D.C.

Regulatory Guide Task ES 401-4 (Draft); "Onsite Meteorological Measurement Program for Uranium Recovery Facilities - Data Acquisition and Report." U.S. Nuclear Regulatory Commission (NRC), Office of Nuclear Regulatory Research, Washington, D.C.

Sedlet, J., and R. A. Wynveen. 1983. Low-Level Radioactive Waste Management Handbook Series - Environmental Monitoring for Low-Level Waste-Disposal Sites. DOE/LLW-13Tg, U.S. Department of Energy, Idaho Falls, Idaho.

U.S. Code of Federal Regulations, Title 10, Part 20 (10 CFR 20); "Standards for Protection Against Radiation."

U.S. Code of Federal Regulations, Title 10, Part 61 (10 CFR 61); "Licensing Requirements for Land Disposal of Radioactive Waste."

U.S. Environmental Protection Agency (EPA). 1972. Environmental Radioactivity Surveillance Guide. EPA-ORP/SID 72-2, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1976. Monitoring Ground-Water Quality: Monitoring Methodology. EPA 600/4-76-026, U.S. Environmental Protection Agency, Las Vegas, Nevada.

U.S. Environmental Protection Agency (EPA). 1982. Handbook for Sampling and Sample Preservation of Water and Wastewater. EPA 600/4-82-029, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1975. Radiological Environmental Monitoring by NRC Licensees for Routine Operations of Nuclear Facilities. NUREG-0475, NRC Task Group, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1987. Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility, Safety Analysis Report. NUREG-1200, U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988 (Draft). "Technical Position Paper -Environmental Monitoring of Low-Level Waste Disposal Facilities." U.S. Nuclear Regulatory Commission Division of Low Level Waste Management and Decommissioning, Washington, D.C.

Warriner, J. B., and R. D. Bennett. 1985. Alternative Methods for Disposal of Low-Level Radioactive Wastes, Task 2a: Technical Requirements for Belowground Vault Disposal of Low-Level Radioactive Waste. NUREG/CR-3774, Vol. 2, U.S. Nuclear Regulatory Commission, Washington, D.C.

Watson, J. E. 1980. "Upgrading Environmental Radiation Data." In Quality Assurance for Environmental Monitoring Programs. EPA 520/1-80-012, U.S. Environmental Protection Agency, Washington, D.C.

Winer, B. J. 1971. Statistical Principles in Experimental Design. McGraw-Hill, New York, New York

4.0 OPERATIONAL ENVIRONMENTAL MONITORING PROGRAMS

The operational phase of environmental monitoring programs for alternative methods of disposing of low-level radioactive waste will be similar in many respects to the overall monitoring principles identified in Section 3.0, Preoperational Environmental Monitoring Programs, with only minor modifications. Therefore, this section emphasizes those aspects of operational environmental monitoring programs that differ from the criteria provided in Sections 3.1 through 3.6 of the preoperational monitoring chapter.

The operational environmental monitoring programs for alternative methods of disposing of low-level radioactive waste require sampling and measurements of those media that may provide an exposure pathway to the public. Hence, considerable care must be taken in designing and implementing these programs to be in concert with those data collected during the preoperational monitoring program. The programs should also be technically sound and sufficiently broad to address any issues that may be raised by the public.

4.1 PROGRAM OBJECTIVES

The operational environmental monitoring program objectives were noted in Section 1.4 and summarized in Table 1.1 of this document. In essence, they are to determine environmental levels of radiological and selected nonradiological parameters with respect to site operations (i.e., above background levels) and to demonstrate compliance with applicable regulations. This latter objective requires that the applicant assess the potential public exposure from site operations for comparison with the annual radiation dose criteria provided in the regulations.

4.2 MONITORING PROGRAM ADMINISTRATIVE ORGANIZATION

The monitoring program organization will be similar in format and content to that provided in Section 3.2 of the preoperational environmental monitoring chapter. However, staffing requirements will probably differ somewhat between the three disposal alternatives during the operational phase. These differences are based on the personnel requirements projected to be needed for each of the alternative disposal methods provided in the Conceptual Design Report (Rogers and Associates 1987). Because environmental monitoring program tasks represent only a portion of the radiation protection staff requirements, only those radiation protection personnel identified by Rogers and Associates as supplementary to the base staff were assumed to be needed for environmental monitoring. A summary of these staffing requirements for the operational phase of the environmental monitoring programs for low-level waste disposal facilities (LLWDFs) are provided in Table 4.1.

During the operational phase, the personnel training program must include at least annual radiation safety training for all staff members who are or will be involved in collecting, labelling, receiving, or analyzing samples from the environmental monitoring program. The radiation safety

TABLE 4.1. Summary of Staffing Requirements for Radiation Protection Aspects of Operational Phase Environmental Monitoring Programs for Alternative Disposal Methods

	Number Required by Disposal Alternative			
	BGV	EMCB	AUS	SLB
Health Physics Techicians	1	3	2	1

training program content and attendance lists shall be maintained within the records specified in Section 3.6 of this document.

Table 4.2 is a suggested checklist for use by the U.S. Nuclear Regulatory Commission (NRC) reviewer(s) to evaluate the acceptability of the applicant's environmental monitoring program administrative organization during the operational phase.

TABLE 4.2. Operational Phase Administrative Organization - Review Criteria Checklist

Subject	Review Criteria
Bases	10 CFR 61.11(b); Reg. Guide 8.2
Lines of Authority	Rad safety access to vice-president
Personnel qualifications	1 health physicist; 1-3 Health Physics techs (see Table 4.1)
Personnel training	Rad safety training at least annually
Staff maintenance	Discuss plan to be used to maintain an adequate complement of trained staff (as defined above)

4.3 EQUIPMENT, INSTRUMENTATION, AND FACILITIES

It is anticipated that the three disposal alternatives will require similar equipment, instrumentation, and facilities. However, the numbers of units may differ somewhat because maintenance and storage requirements will vary depending on climatic conditions. The following subsections are equally applicable for sites using any one of the alternatives.

4.3.1 Requirements

The equipment used for sampling, the instrumentation used to measure levels or concentrations of material, and the facilities used to perform analyses, store samples, and house sampling equipment must meet applicable requirements for the licensing of an LLWDF. These requirements are defined in specific sections of the Code of Federal Regulations (CFR). The requirements include 10 CFR 61.12, "Specific Technical Information," item (k), procedures, instrumentation, facilities and equipment; and 10 CFR 61.81, "Tests at Land Disposal Facilities," items (a)(2) and (3) for tests of radiation detection and monitoring instruments and other equipment and devices used in connection with the possession, storage, and disposal of radioactive waste.

There are basically six media to be sampled in the operational phase of LLWDF environmental monitoring programs: 1) airborne particulates and gases, 2) ground water, 3) surface water and surface runoff, 4) soil and sediments, 5) vegetation and other biota, and 6) subsurface, vadose zone gases, and liquids. The information needed to evaluate the impact on the environment resulting from the operation of an LLWDF is essentially the same as that needed for the preoperational phase and, therefore, is not repeated here (see Section 3.3.1).

4.3.2 Discussion

The NRC reviewer needs accurate descriptions of the monitoring locations and the instrumentation, as well as the procedures for sample collection, transport, and analysis, to ensure the production of quality data from environmental monitoring programs. Therefore, the equipment, instrumentation, and facilities should be capable of operating during the facility's lifetime, over extended periods (e.g., from 30 to 50 years). Because most equipment, instruments, and facilities (e.g., monitoring wells) are not expected to last that long, reserve equipment or instruments must be available to replace those that become inoperable. Plans should be included to routinely upgrade equipment as new instruments become available. Plans should also include a well maintenance program to extend the service life of the monitoring wells.

4.3.3 Recommendations

Many documents are available that provide guidance on the use of field equipment and laboratory instruments, a number of which were identified in the preoperational section, Section 3.3.3. These should also be consulted during review of the operational environmental monitoring programs.

Items that need to be addressed for each medium include:

- air - both off-gases and particulates, radiological and nonradiological, sampler design, and the appropriateness of the sample

- vadose zone - both gases and liquids, radiological and nonradiological, sampler design, sample preservation, and the appropriateness of the sample

- ground water - primarily dissolved radiological and nonradiological constituents in a water medium, sampler design, sample collection, and sample preservation

- surface water and runoff - both dissolved and particulates, radiological and nonradiological, sampling procedures, sample preservation, and the adequate sensitivity of the analysis

- sediment and soil - solids only, radiological and nonradiological, sampler design, spacing, appropriateness of the sample, and sample preservation

- vegetation and other biota - sample appropriateness and preservation, mainly radiological analyses with some nonradiological analyses for onsite samples.

4.4 MONITORING PROGRAM IMPLEMENTATION

Although the choice of sites may differ for the application of each of the three disposal alternatives considered in this document, the operational environmental monitoring programs for each disposal alternative are assumed to be the same. However, differences may exist between arid and humid sites, as noted later in this section. The ensuing requirements, discussion, and recommendations are assumed to be equally applicable for sites using each of the disposal alternatives--below-ground vaults, earth-mounded concrete bunkers, augered shafts--as well as shallow-land burial disposal.

4.4.1 Requirements

The regulations applicable to the review of a license application for LLWDFs with respect to the operational environmental monitoring program include the specific sections of 10 CFR 20 and 10 CFR 61 noted in Section 2.0 of this document. These regulations ensure protection of the general population from releases of radioactivity at LLWDFs by requiring a description of the environmental monitoring program [10 CFR 61.12(1)] and that certain types of pathways be analyzed [10 CFR 61.13(a)], and by defining the purpose and location of sampling [10 CFR 61.53(c)] as well as the radiation levels that dictate instrument detection sensitivites [10 CFR 61.13(a) and 10 CFR 20.201].

Pathways to be evaluated (i.e., samples/measurements to be made) - 10 CFR 61.13(a) stipulates that the pathways analyzed for must include "air, soil, ground water, surface water, plant uptake, and exhumation by burrowing animals."

Description of environmental monitoring program - 10 CFR 61.12(1) requires that the applicant provide a description of the environmental monitoring program to be used "to provide data to evaluate potential . . . environmental impacts and the plan for taking corrective measures if migration of radionuclides is indicated."

Purpose and location of sampling - 10 CFR 61.53(c) stipulates that the licensee shall maintain a monitoring program to provide data to evaluate the potential health and environmental impacts during operation of the facility and, further, that "the monitoring system must be capable of providing early warning of releases of radionuclides from the disposal site before they leave the site boundary."

Minimum sensitivity of sampling program - 10 CFR 20.106 provides restrictions on the release of radioactive materials to unrestricted areas such that they "shall not exceed the concentrations specified in Appendix B, Table II;" the last sentence in paragraph 10 CFR 61.13(a) specifies that the analyses must clearly demonstrate that the "exposure to humans from the release of radioactivity will not exceed the limits set forth in § 61.41." Similarly, 10 CFR 61.53(b) stipulates that the licensee have plans for taking corrective action if radionuclide migration from the site would indicate "that the performance objectives of Subpart C [§ 61.41] may not be met." These requirements control the analytical/instrument sensitivity required for laboratory and/or field measurements.

4.4.2 Discussion

Because the basic radiation standards are given in terms of dose to people, it is desirable to use the estimates of potential radiation exposure of the public from activities at LLWDFs to aid in the design and implementation of operational environmental monitoring programs. The potential exposures from radioactive waste disposed of at the reference sites can occur either from individuals encountering the waste directly or from the waste migrating from its disposed location into areas inhabited by or used by people for production of food. A discussion of the potential critical radiological pathways for alternative low-level waste technologies is provided in Section 1.5.3 of this document. That qualitative analysis provides a preliminary discussion of the environmental pathways/media that should be considered in the review of an applicant's operational environmental monitoring program.

The primary focus of the NRC review of the operational environmental monitoring program for LLWDFs is on the radiological requirements of 10 CFR 61 and 10 CFR 20. However, the operators of an LLWDF need to comply with the regulatory requirements of other federal, state, and local agencies. Thus, for completeness, it will be helpful for the NRC staff to be aware of and to utilize the U.S. Environmental Protection Agency (EPA) radiological and nonradiological environmental monitoring requirements identified in the list below when evaluating the adequacy of an applicant's operational environmental monitoring plan:

- general monitoring requirements of 40 CFR 61.14 for airborne radionuclide emissions from facilities

- specific monitoring requirements of 40 CFR 61.103 for airborne radionuclide emissions from facilities

- incorporation of ambient air monitoring reference and equivalent methods of 40 CFR 53.1 through 53.33

- ambient air monitoring methods, siting of instruments and instrument probes, operating schedule, and special purpose monitoring criteria of 40 CFR 58.11 through 58.14

- national primary and secondary ambient air quality standards of 40 CFR 50.1 through 50.12 including reference methods for the determination of criteria pollutants

- microbiological contaminant sampling and analytical requirements of 40 CFR 141.21 for drinking water

- turbidity sampling and analytical requirements of 40 CFR 141.22 for drinking water

- inorganic chemical sampling and analytical requirements of 40 CFR 141.23 for drinking water

- sampling and analytical requirements of 40 CFR 141.24 for organic chemicals, other than total trihalomethanes, in drinking water

- analytical methods of 40 CFR 141.25 for radioactivity in drinking water

- monitoring frequency of 40 CFR 141.26 for radioactivity in community drinking water systems

- sampling, analytical, and other requirements of 40 CFR 141.30 for total trihalomethanes in drinking water

- national secondary drinking water standards of 40 CFR 143.4 for monitoring of drinking water

- National Pollutant Discharge Elimination System (NPDES) liquid discharge monitoring requirements of 40 CFR 125.62

- monitoring requirements of 40 CFR 6.607 for implementing National Environmental Policy Act (NEPA) on new source NPDES programs

4.4.3 Recommendations

The monitoring programs themselves should be consistent with the draft "Technical Position Paper - Environmental Monitoring of Low-Level Radioactive Waste Disposal Facilities" (NRC 1988). Other NRC guidance can be found in Regulatory Guide 4.1; NUREG-0475 (NRC 1975); and the addendum to NUREG/CR-0570 (Denham et al. 1981). Additional guidance for environmental monitoring programs at low-level waste sites is included in Appendix A of this document, as well as in the Low-Level Radioactive Waste Management Handbook (Sedlet and Wynveen 1983).

The applicant's description of the operational environmental monitoring program should also include maps identifying both onsite and offsite monitoring locations, the frequency of sampling and analysis, the types of analyses to be performed and their frequency, as well as other parameters noted in the preoperational environmental monitoring program (see Section 3.4.3). Applicable components of the operational program for NRC review include the following:

- Meteorological information should be provided as the basis for locating sampling stations, especially for air, soil and vegetation collection.
- Hydrological information should be provided as the basis for surface and subsurface water sampling locations and sampling frequencies.
- Geological information should be provided as the basis for locating ambient radiation measurements and for siting soil sampling locations.
- Biological information should be used in conjunction with local fish and game department information to establish those flora and fauna species to be sampled.
- Direct radiation measurement locations should be based on the proposed waste-handling and emplacement activities and the location and distribution of the local population that could be exposed to direct radiation emanating from the site.

The operational environmental monitoring programs should emphasize the measurement of short-term releases of radionuclides that could create a significant environmental impact. To preclude an individual in the general population from being exposed to radiation levels or concentrations of radioactive materials that would exceed regulatory limits, administrative action levels should be established. These action levels are not limits, but administrative thresholds that trigger an investigation of the circumstances causing an elevated concentration. To ensure that environmental standards are met, the administrative action levels should be set at some fraction (e.g., 1/3 to 1/5 to 1/10) of the applicable limit(s). Because the fraction is to be used only as an administrative tool, some flexibility should be allowed in the setting of this level. The background level of the parameters at the specific site should also be considered in setting these action levels. For example, if historical site data show that fluctuations are not significant enough to suggest that peak values might violate the applicable environmental standards (at the 95% confidence level), then the administrative action level could be justifiably set at a higher fraction of the applicable limits. Administrative action levels that would trigger investigative action following significant increases in actual measured concentrations (such as a definite upward trend in one or more media) should also be established. That is, administrative action levels are likely to involve more than one level for a given contaminant and environmental medium.

Because the administrative action levels are expected to include more than one level, the specific action taken is related to the environmental level and corresponding regulation. At the lowest statistically significant level (with 95% confidence) above background (e.g., some multiple of the background value), the action taken would begin with analytical confirmation (e.g., recounting the sample or another aliquot of the same sample). The action taken at a higher level (e.g., some fraction of the regulatory limit) would involve further environmental investigation (e.g., additional sampling or sampling of different media) to determine the cause of the elevated concentration. Other actions could involve an increased frequency of sampling as well as an investigation of current operational practices. A discussion of the administrative action levels and the proposed increased monitoring activities associated therewith should be reflected in the license application and would be expected to become a part of the license conditions.

For radiological components, an upper administrative action level of 25% of the applicable dose standards is suggested. Because measurements of nonradiological constituents are only made for purposes of assessing or evaluating the potential for radionuclide migration, any measurable increase in nonradiological constituents that is significantly (at the 95% confidence level) above the baseline levels established during the preoperational environmental monitoring phase would be expected to be investigated.

The review criteria checklist in Table 4.3 is provided for use by the NRC reviewer(s) to evaluate the acceptability of the applicant's operational environmental monitoring program.

TABLE 4.3. Operational Environmental Monitoring Program - Review Criteria Checklist

Subject	Review Criteria
Bases	10 CFR 61.13(a) and (c); 10 CFR 61.53(a) and (c)
Appropriate sampling media	10 CFR 61.13(a); at least air, soil, ground and surface water, plants, and burrowing animals
Appropriate sampling/ measurement locations	10 CFR 61.53(c)
Adequate detection sensitivities	Table II, Appendix B of 10 CFR 20
Critical nuclides included	Based on pathway analysis using standard models (e.g., AIRDOS-EPA, MAXI, etc.)
Direct radiation measurements	Based on consideration as a potential critical pathway
Sampling/measurement frequency	10 CFR 61.13(c), 10 CFR 61.53(a) and (c)

Table 4.3 (cont)

Subject	Review Criteria
Background/control locations	At least one per medium/measurement
Special samples	Precipitation, especially for humid sites
Administrative action levels	Based on 10 CFR 61.53(b); upper level $\leq$25% of applicable environmental dose standards for radiological parameters

4.5 DATA RECORDING AND STATISTICAL ANALYSES

Data recording and statistical analyses are similar in format and content to that provided in Section 3.5 of the preoperational environmental monitoring section and, therefore, are not repeated here. One additional consideration is that no single concentration values are to be used to determine compliance with regulatory limits.

4.6 DATA REPORTING

The requirements and recommendations on data reporting apply equally for all sites using any of the three alternative disposal techniques. This section provides a list and discussion of as well as recommendations for those reporting requirements.

4.6.1 Requirements

Each licensee must maintain records and make reports to comply with the radiation protection standards of 10 CFR 20. An applicant's monitoring procedures must include provisions to meet the reporting requirements of excessive levels and concentrations, as specified in Subsections 20.403 and 20.405. The important aspects of reporting and notification requirements of these regulations that apply to environmental monitoring and which must be addressed in the license application are as follows:

- Each licensee shall immediately report to the NRC or regulatory authority any events involving byproduct, source, or special nuclear material possessed by the licensee that may have caused or threatens to cause the release of radioactive material in concentrations that, if averaged over a period of 24 hours, would exceed 5000 times the limits specified for such materials in Appendix B, Table II, of 10 CFR 20.
- Within 24 hours a licensee shall report to the NRC or regulatory authority any event that may have caused or threatens to cause the release of radioactive material in concentrations that, if averaged over a period of 24 hours, would exceed 500 times the limits specified in Appendix B, Table II of 10 CFR 20.

- The reporting of the above situations is to be by telephone and by telegram, mailgram, or facsimile to the appropriate NRC Regional Office.

- Incidents that result in levels of radiation or concentrations of radioactive material in a restricted area in excess of applicable limits in the license or levels of radiation or concentrations of radioactive material (whether or not involving excessive exposure of any individual) in an unrestricted area in excess of ten times any applicable limit shall be reported in writing to the NRC or regulatory authority within 30 days of the occurrence and shall include the following environmental monitoring information:

  - the levels of radiation and concentrations of radioactive material involved

  - the cause of the exposure, levels, or concentrations

  - corrective steps taken or planned to prevent a recurrence.

In addition, the records and reporting requirements of 10 CFR 61.80, must be met. The records and reporting requirements that apply to environmental monitoring are as follows:

- Licensee shall maintain any records and make reports as may be required by the conditions of the license or by the rules, regulations, and orders of the NRC.

- Records must be maintained for a period specified by the appropriate regulations or by license conditions.

- Records may consist of the original or a reproduced copy or microfilm if this reproduced copy or microfilm is capable of producing copy that is clear and legible at the end of the required retention period.

- If there is a conflict between the NRC regulations, license conditions, or other written NRC approval or authorization pertaining to the retention period for the same type of record, the longest retention period specified takes precedence.

- If a retention period is not otherwise specified, records must be maintained and transferred to the officials listed below as a condition of license termination unless the NRC otherwise authorizes their disposition:

  - chief executive of the nearest municipality

  - chief executive of the county in which the facility is located

  - the county zoning board or land development and planning agency

- the state governor and other state, local, and federal governmental agencies as designated by the NRC at the time of license termination.

- Each licensee shall submit annual reports to the appropriate NRC regional office with copies to the Director of the Office of Enforcement and the Director of the Division of Low-Level Waste Management and Decommissioning. Reports shall be submitted by the end of the first calendar quarter of each year for the preceding year and shall contain the following:

  - specification of the quantity of each of the principal radionuclides released to unrestricted areas in liquid and in airborne effluents during the preceding year

  - description of any instances in which observed site characteristics were significantly different from those described in the application for the license

  - listings of radioactive materials released during the reporting period, monitoring results, or maintenance performed that differ significantly from those expected, as described in documents prepared as part of the licensing action.

4.6.2 Discussion

The reporting of environmental monitoring data is to ensure that environmental conditions of the facility are documented and preserved for future evaluations. The applicant should clearly state that monitoring records will be retained indefinitely until termination of the license, at which time the records will be transferred to those organizations specified in 10 CFR 61.80.

While the primary monitoring and reporting concerns of the NRC or regulatory authority are the radiological conditions of the site, there will be other environmental monitoring and reporting specified by federal, state, and local agencies, including items such as permits, NEPA documents, environmental regulations, zoning, and land use. Although the responsibility for compliance with these reporting requirements is with other agencies, the timely submission of these reports could affect the continued operation of the facility and will likely be a license condition. The licensee should define the environmental reporting that is required to be made on the facility.

4.6.3 Recommendations

In addition to the reporting requirements of 10 CFR 61, the license application should specify the reporting requirements and reporting schedule that must be made to all agencies. This should include reporting on:

- all state or federal environmental permits (NPDES, prevention of significant deterioration)
- monitoring and compliance activities to demonstrate compliance with environmental legislation [Resource Conservation and Recovery Act (RCRA), Clean Air Act of 1977, Safe Drinking Water Act, endangered species list, state environmental laws]
- any reporting requirements of local governments on items such as land use or zoning
- any reporting that is required by any state or federal environmental impact statements prepared for the licensed facility
- any reports that are specified in the license.

The retention of environmental monitoring records should be clearly specified in the license application. Records pertaining to environmental monitoring and surveillance during the preoperational and operational phases of the licensed project should be retained until license termination, at which time the records are transferred to the parties specified in 10 CFR 61.80(e). These records should include:

- concentrations and volumes of all radionuclides released to unrestricted areas
- concentrations of radionuclides measured in the environment
- all environmental dose measurements
- all radiation survey data
- all ground-water measurements.

A data reporting review checklist is provided in Table 4.4 to aid the NRC reviewer(s).

TABLE 4.4. Data Reporting - Review Criteria Checklist

Subject	Review Criteria
Immediate NRC notification	24-hr average concentrations >5000 x limits in 10 CFR 20 App. B, Table II
24-hr notification	24-hr average concentrations >500 x limits in 10 CFR 20 App. B, Table II
30-day written notification	Levels of radiation or concentration of radioactive materials in an unrestricted area >10 x applicable limits

TABLE 4.4 (cont)

Subject	Review Criteria
Records maintenance	Maintain records per license conditions in 10 CFR 61.80
Reporting to NRC or regulatory authority	10 CFR 61.80(i)(1) and (2); annual reporting of environmental monitoring data by end of first calendar quarter
Reporting to other agencies	Identify all state or federal environmental permits
Records retention	As clearly specified in license application

4.7 QUALITY ASSURANCE AND CONTROL

Quality assurance and quality control is similar in format and content to that provided in Section 3.7 of the preoperational environmental monitoring chapter and therefore is not repeated here.

4.8 REFERENCES

Denham, D. H., P. A. Eddy, K. A. Hawley, R. E. Jaquish and J. P. Corley. 1981. Technology, Safety and Costs of Decommissioning a Reference Low-Level Waste Burial Ground - Environmental Surveillance Programs. NUREG/CR-0570 Addendum, U.S. Nuclear Regulatory Commission, Washington, D.C.

Lutton, R. J., P. G. Malone, R. B. Meade and D. M. Patrick. 1982. Parameters for Characterizing Sites for Disposal of Low-Level Radioactive Waste. NUREG/CR-2700, U.S. Nuclear Regulatory Commission, Washington, D.C.

Miller, W. O., and R. D. Bennett. 1985. Alternative Methods for Disposal of Low-Level Radioactive Wastes, Task 2c: Technical Requirements for Earth Mounted Concrete Bunker Disposal of Low-Level Radioactive Waste. NUREG/CR-3774, Vol. 4, U.S. Nuclear Regulatory Commission, Washington, D.C.

Regulatory Guide 4.1 (1975); "Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants." U.S. Nuclear Regulatory Commission, Office of Standards Development, Washington, D.C.

Regulatory Guide 8.2 (1973); "Guide for Administrative Practices in Radiation Monitoring." U.S. Atomic Energy Commission, Directorate of Regulatory Standards, Washington, D.C.

Rogers and Associates Engineering Corporation. 1987. Conceptual Design Report, Alternative Concepts for Low-Level Radioactive Waste Disposal. DOE/LLW-60T, U.S. Department of Energy, Washington, D.C.

Sedlet, J., and R. A. Wynveen. 1983. Low-Level Radioactive Waste Management Handbook Series - Environmental Monitoring for Low-Level Waste-Disposal Sites. DOE/LLW-13Tg, U.S. Department of Energy, Idaho Falls, Idaho.

U.S. Code of Federal Regulations, Title 10, Part 20 (10 CFR 20). "Standards for Protection Against Radiation."

U.S. Code of Federal Regulations, Title 10, Part 61 (10 CFR 61); "Licensing Requirements for Land Disposal of Radioactive Waste."

U.S. Code of Federal Regulations, Title 40, Part 6 (40 CRR 6); "Procedures for Implementing the Requirements of the Council on Environmental Quality on the National Environmental Policy Act (NEPA)."

U.S. Code of Federal Regulations, Title 40, Part 50 (40 CFR 50); "National Primary and Secondary Ambient Air Quality Standards."

U.S. Code of Federal Regulations, Title 40, Part 53 (40 CFR 53); "Ambient Air Monitoring Reference and Equivalent Methods."

U.S. Code of Federal Regulations, Title 40, Part 58 (40 CFR 58); "Ambient Air Quality Surveillance."

U.S. Code of Federal Regulations, Title 40, Part 61 (40 CFR 61); "Regulations on National Emission Standards for Hazardous Air Pollutants;" especially Subpart I - "National Emission Standard for Radionuclide Emissions from Facilities Licensed by the Nuclear Regulatory Commission (NRC) and Federal Facilities Not Covered by Subpart H [DOE Facilities]."

U.S. Code of Federal Regulations, Title 40, Part 125 (40 CFR 125); "Criteria and Standards for the National Pollutant Discharge Elimination System."

U.S. Code of Federal Regulations, Title 40, Part 141 (40 CFR 141); "National Primary Drinking Water Regulations."

U.S. Code of Federal Regulations, Title 40, Part 143 (40 CFR 143); "National Secondary Drinking Water Regulations."

U.S. Nuclear Regulatory Commission (NRC). 1975. Radiological Environmental Monitoring by NRC Licensees for Routine Operations of Nuclear Facilities. NUREG-0475, U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988 (Draft). "Draft Technical Position Paper - Environmental Monitoring of Low-Level Waste Disposal Facilities." U.S. Nuclear Regulatory Commission, Washington, D.C.

5.0 POSTOPERATIONAL ENVIRONMENTAL MONITORING PROGRAMS

The postoperational environmental monitoring programs for alternative methods of low-level radioactive waste disposal will be similar in many respects to the principles of preoperational and operational programs identified in Sections 3.0 and 4.0. Therefore, this section emphasizes only those aspects of postoperational environmental monitoring programs for low-level waste disposal facilities (LLWDFs) that differ from the criteria provided in Sections 3.1 through 3.6 and 4.1 through 4.6.

5.1 PROGRAM OBJECTIVES

The postoperational environmental monitoring program objectives for LLWDFs were provided in Section 1.4 and summarized in Table 1.1 of this document. In summary, the objectives are to continue to demonstrate compliance with regulations and to demonstrate that performance objectives are being met. Hence, these programs will require sampling and measurements of those media that may provide a long-term exposure pathway to the public from the closed site. The proposed postoperational environmental monitoring program will likely include plans for future decreased monitoring during the long-term care period. These programs must be conducted in concert with those of the preoperational and operational environmental monitoring periods to ensure data comparability and program continuity.

5.2 MONITORING PROGRAM ADMINISTRATIVE ORGANIZATION

The monitoring program organization will be similar in format and content to that provided in Section 3.2 of the preoperational environmental monitoring chapter, with possible modifications because of the reduced staffing needs during the postoperational period. During the short-term (5-year) phase of the postoperational period it is expected that the staffing requirements will remain as identified in Section 4.2, for the operational program, but will be effectively eliminated for the licensee when the license is terminated and the site is transferred to the owner for the 100-year long-term period. During the long-term phase of the postoperational period it is anticipated that any health physics support (professional or technician) will be obtained through contract or consultation only.

5.3 EQUIPMENT, INSTRUMENTATION, AND FACILITIES

The requirements for equipment, instrumentation, and facilities as defined in Section 4.3 of this document will remain in effect during the short-term phase of the postoperational period, after which environmental monitoring needs are expected to be drastically reduced. Although the frequency of sampling and analyses may be diminished based on the experience gained during the operational environmental monitoring period, several media are expected to be sampled in the early postoperational phase: 1) airborne particulates and gases, 2) ground water, 3) surface water and surface run off, 4) soil and sediments, 5) vegetation and other biota, and 6) subsurface, vadose zone gases and liquids. The types of information needed to evaluate the impact on the environment in the postoperational phase are identical to those provided in the operational phase (see Section 4.3.1) and are therefore not repeated here.

5.4 MONITORING PROGRAM IMPLEMENTATION

Although the choice of sites may differ for the application of each of the three disposal alternatives considered in this document, the postoperational environmental monitoring programs are assumed to be identical to the operational program. However, the number of sampling stations will be diminished, especially after the 5-year short-term care period, and the frequency of sampling/analysis will be less frequent than that indicated for the operational phase.

5.4.1 Requirements

The regulations applicable to the review of a LLWDF license application with respect to the postoperational phase environmental monitoring program include some of the same specific sections of 10 CFR 61 and 10 CFR 20 identified in Section 2.0 of this document. In particular, these include requirements for long-term analyses [10 CFR 61.13(d)], the duration of the sampling program (10 CFR 61.29), the implementation and need for monitoring by the disposal site operator [10 CFR 61.30(a)(4) and 10 CFR 61.44], and the instrument detection sensitivity [10 CFR 20.106, 10 CFR 61.13(a), and 10 CFR 61.53(b)] used to evaluate potential releases of radioactivity at low-level waste sites.

Long-term analyses - 10 CFR 61.13(d) stipulates that the analyses should include infiltration (e.g., vadose zone and ground water), covers, adjacent soils, and surface drainage.

Duration of postoperational program - 10 CFR 61.29 specifies that the licensee shall monitor the disposal site and that responsibility must be maintained by the licensee for 5 years after closure.

Implementation and need for sampling - 10 CFR 61.30(a)(4) requires that the postclosure monitoring program is operational for implementation by the disposal site owner while 10 CFR 61.44 identifies the need for monitoring after site closure.

Minimum sensitivities - 10 CFR 20.106 provides restrictions on the release of radioactive materials to unrestricted areas such that they "shall not exceed the concentrations specified in Appendix B, Table II;" the last sentence in paragraph 10 CFR 61.13(a) specifies that the analyses must clearly demonstrate that the "exposure to humans from the release of radioactivity will not exceed the limits set forth in § 61.41;" and, similarly, 10 CFR 61.53(b) stipulates that the licensee have plans for taking corrective action if radionuclide migration from the site would indicate "that the performance objectives of Subpart C [§ 61.41] may not be met." These regulations provide the basis for setting minimum detection levels for the field and laboratory instruments used in the postoperational monitoring program.

5.4.2 Discussion

As noted in the DOE Low-Level Radioactive Waste Management Handbook Series (Sedlet and Wynveen 1983), the specifics of the postoperational environmental monitoring program will be principally influenced by the results of the operational program. Decisions on whether to continue or terminate particular monitoring program features should be based on the data trends during operation as well as the potential for change over long time periods, such as may occur in ground water. Those items that may be politically sensitive in the region should also be considered for continued monitoring (e.g., if, in an agricultural region, even infrequent sampling helps provide continued assurance that contaminants are not entering the food chain).

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 further cover the disposed wastes. If no leakage or rupture of waste containers has occurred, then, under routine operations, the surface should be free of removable or resuspendable contamination.

The most probable primary long-term pathway for radionuclide release will be transport through ground water. Therefore, the major emphasis should be on monitoring subsurface water. Sampling should be concentrated on the vadose zone and ground water in onsite and perimeter wells, and in the nearest offsite sources of subsurface drinking or irrigation water. If the subsurface water can eventually reach surface streams, rivers, or lakes, these water bodies should also be sampled at a location downstream from the ground-water entry point.

Another potential pathway to humans is through rooted plants, grasses, or coniferous trees grown on the surface of the site to control soil erosion. Samples of these materials should be collected at appropriate times, e.g., normal harvest time for crops, and analyzed to determine any root uptake of pollutants. Samples of the burrowing animals that may inhabit the site should also be collected. If the biobarriers are effective, the potential impact from these pathways should be negligible.

The analysis scheme should rely principally on the determination of tritiated water, gamma-ray emitters, a few selected radionuclides, including strontium-90, and the chemical pollutant leachate indicators. These should provide a relatively complete picture on the rate of movement of specific substances from the disposed wastes.

In addition to the limited environmental sampling and analysis to be conducted in the postoperational phase, a surveillance and monitoring program would be conducted for the initial portion of the institutional control period. The surveillance program would provide for physical inspection of the site and the performance of any required repairs to maintain the site integrity. Examples of such items are: repair and maintain the perimeter fence; fill any surface subsidence of the disposal units/trenches; check and service equipment; correct any effects of vandalism; and correct any problems and damage caused by erosion. This would be part of an overall maintenance and administration program.

The primary focus of the U.S. Nuclear Regulatory Commission (NRC) review of the postoperational environmental monitoring program for LLWDFs is on the NRC-associated radiological requirements of 10 CFR 61. However, the review process should not overlook the other applicable federal, state, and local regulatory requirements. These other radiological and nonradiological parameter requirements are discussed in the chapter on operational monitoring requirements (Section 4.4.2). Postoperational environmental monitoring plans should be designed to accommodate the need for tracking these other constituents that have proven to be of concern during the site operational period.

5.4.3 Recommendations

The postoperational environmental monitoring programs should be consistent with the preoperational and operational environmental monitoring programs as well as the draft "Technical Position Paper - Environmental Monitoring of Low-Level Waste Disposal Facilities" (NRC 1988).

To preclude an individual in the general population from being exposed to concentrations of contaminants above the regulatory standards, an administrative action level should be established that would trigger investigative action following the detection or observation of significant (at the 95% confidence level) increases in environmental radionuclide levels. It is suggested that the upper administrative action level of the operational phase of 25% of the applicable dose standards be maintained. But, because there are no longer operational activities at the site that could increase the potential for radionuclide release, more attention should be paid to the need for lower administrative action levels (e.g., a small multiple of the background). Such action levels should be set so that any measurable (at the 95% confidence level) increase in radionuclide concentrations above the background levels established during the preoperational monitoring phase will be investigated.

It is expected that the NRC reviewer(s) will utilize the checklist provided in Table 5.1 to evaluate the acceptability of the applicant's discussion of the postoperational environmental monitoring program.

5.5 DATA RECORDING AND STATISTICAL ANALYSES

Data recording and statistic l analyses are assumed to be similar in format and content to that described in Section 3.5 of the preoperational environmental monitoring chapter and as modified in Section 4.5 of the operational environmental monitoring chapter. Therefore, those discussions are not repeated here.

TABLE 5.1. Postoperational Environmental Monitoring Program - Review Criteria Checklist

Subject	Review Criteria
a. Short-Term Phase (5 years)	10 CFR 61.29; 10 CFR 61.53(d); 10 CFR 20.106
Bases	
Program duration	10 CFR 61.29; maintained by licensee for 5 years
Early warning of releases	10 CFR 61.53(d)
Appropriate sampling media	10 CFR 61.53(d); at least gases, soil, ground and surface water, plants, and burrowing animals
Appropriate sampling locations	10 CFR 61.53(d); consistent with operational monitoring program
Adequate detection sensitivities	Table II, Appendix B of 10 CFR 20
Critical nuclides included	Based on operating history and pathway analysis using standard models (e.g., AIRDOS-EPA, MAXI, etc.)
Sampling frequency	At least annually
Background/control locations	At least one per medium
Administrative action levels	Based on 10 CFR 61.53(d); upper level ≤ 25% of applicable environmental dose standards, lower level at significant increase (at 95% confidence level) above background levels
b. Long-Term Phase (100 years)	
Bases	10 CFR 61.13(d); 10 CFR 61.30(a)(4); 10 CFR 61.44
Appropriate sampling media	At least gases, ground water, and burrowing animals
Appropriate sampling locations	10 CFR 61.30(a)(4); consistent with short-term phase post-operational monitoring program
Administrative action levels	Based on operating history and environmental monitoring experience
Appropriate surveillance activities	10 CFR 61.13(d); erosion slope failure, settlement, and infiltration
Surveillance frequency	10 CFR 61.44; minimal requirements after site closure; at least annually, or as experience dictates

5.6 DATA REPORTING

The reporting of environmental monitoring data is to ensure that environmental conditions of the facility are documented and preserved for future evaluations. Environmental monitoring records are to be retained indefinitely until termination of the license, at which time the records are to be transferred to those organizations specified in 10 CFR 61.80.

If a release of radionuclides occurs during the postoperational period, the reporting requirements of 10 CFR 61 and CFR 20 as specified in Section 4.6 must be strictly followed. In addition, although the environmental data obtained during the postoperational phase will be greatly diminished during this period compared to the operational phase, records must still be maintained as summarized in Section 4.6 of this document and annual reports provided as specified in 10 CFR 61.80(i)(1) and (2).

5.7 QUALITY ASSURANCE AND CONTROL

This section is assumed to be similar in format and content to that provided in Section 3.7 of the preoperational environmental monitoring chapter and, therefore, is not repeated here.

5.8 REFERENCES

Sedlet, J., and R. A. Wynveen. 1983. Low-Level Radioactive Waste Management Handbook Series - Environmental Monitoring for Low-Level Waste-Disposal Sites. DOE/LLW-13Tg, U.S. Department of Energy, Idaho Falls, Idaho.

U.S. Code of Federal Regulations, Title 10, Part 20 (10 CFR 20); "Standards for Protection Against Radiation."

U.S. Code of Federal Regulations, Title 10, Part 61 (10 CFR 61); "Licensing Requirements for Land Disposal of Radioactive Waste."

U.S. Nuclear Regulatory Commission. 1988 (Draft). "Draft Technical Position Paper - Environmental Monitoring of Low-Level Waste Disposal Facilities." U.S. Nuclear Regulatory Commission, Washington, D.C.

6.0 SUMMARY

This section is divided into three parts, 1) a summary of the environmental monitoring requirements from the Code of Federal Regulations (10 CFR 61 and 10 CFR 20), 2) a summary of the review criteria to be used by the U.S. Nuclear Regulatory Commission (NRC) in reviewing license applications for low-level waste disposal facilities (LLWDFs), and 3) a summary of the types of environmental monitoring to be conducted at sites implementing each of the three alternative disposal methods--below-ground vaults (BGV), earth-mounded concrete bunkers (EMCB), augered shafts (AUS)--considered in this document. The latter summary includes a similar summary for shallow-land burial/disposal (SLB), for comparison. The review criteria summary is provided in tabular format, excerpted from the review criteria checklists provided in Sections 3.0, preoperational; 4.0, operational; and 5.0 postoperational.

6.1 APPLICABLE REGULATIONS

The regulations applicable to the review of a license application for an LLWDF are found primarily in the CFR, Title 10, Parts 61 and 20. Although not enforceable by the NRC, Title 40 of the CFR also contains U.S. Environmental Protection Agency (EPA) regulations that may influence environmental monitoring programs for low-level radioactive waste disposal operations. Specific parts of the EPA regulations include:

- 40 CFR 6, "Procedures for Implementing the Requirements of the Council on Environmental Quality on the National Environmental Policy Act (NEPA)"
- 40 CFR 50, "National Primary and Secondary Ambient Air Quality Standards"
- 40 CFR 53, "Ambient Air Monitoring Reference and Equivalent Methods"
- 40 CFR 58, "Ambient Air Quality Surveillance"
- 40 CFR 61, "National Emission Standards for Hazardous Air Pollutants (NESHAPS)"
- 40 CFR 125, "Criteria and Standards for the National Pollutant Discharge Elimination System (NPDES)"
- 40 CFR 141, "National Interim Primary Drinking Water Regulations"
- 40 CFR 143, "National Secondary Drinking Water Standards."

6.1.1 10 CFR 61 - License Requirements for Land Disposal of Radioactive Waste

Title 10, Part 61, of the CFR establishes, for land disposal of radioactive waste, the procedures, criteria, terms, and conditions on which the NRC issues licenses for the disposal of radioactive wastes containing byproduct, source and special nuclear material received from other persons. The regulations applicable to the areas of license review as it applies to environmental monitoring are included in specific sections of 10 CFR 61.7 through 61.80.

<u>10 CFR 61.7 - Concepts</u>

- Licensee must remain at site for the 5-year post-closure period to assure site is ready for institutional control.
- Site owner must carry out a postoperational monitoring program to assure continued satisfactory disposal site performance.

<u>10 CFR 61.11 - General Information</u>

- Identity of applicant (i.e., business, location, names and addresses of partners/principal officers).
- Staff qualifications, including training and experience, plus organizational structure and responsibilities.
- Site description, location, proposed activities, types and quantities of radioactive waste to be handled, other land use, and description of facilities and equipment.
- Proposed construction, waste receipt/emplacement schedules.

<u>10 CFR 61.12 - Specific Technical Information</u>

- Description of radioactive material to be processed.
- Quality controls, radiation safety control and monitoring, and environmental monitoring program.

<u>10 CFR 61.13 - Technical Analyses</u>

- Evaluation of air, soil, ground water, surface water, plant uptake, and exhumation by burrowing animals to demonstrate population protection from releases of radioactivity.
- Demonstration that adequate barriers to inadvertent intrusion are provided.
- Assessment of routine operations and likely accidents to assure that exposures will meet 10 CFR 20 requirements.
- Assessment of long-term site stability to preclude need for ongoing maintenance following closure.

10 CFR 61.41 - Protection of the General Population from Releases of Radioactivity

- Concentrations of radioactive material released to general environment must not result in annual doses >25 mrem whole body, >75 mrem thyroid, or >25 mrem to any other organ of any member of the public.

- Releases of radioactivity to general environment should be maintained "as low as is reasonably achievable" (ALARA).

10 CFR 61.29 - Post-Closure Observation and Maintenance

- Requirement for licensee to maintain postoperational monitoring program for 5 years following closure, or for a shorter or longer time period based on site-specific conditions.

10 CFR 61.30 - Transfer of License

- Post-closure monitoring program is to be operational for implementation by the site owner following the short-term postoperational period.

10 CFR 61.42 - Protection of Individuals from Inadvertent Intrusion

- Design, operation, and closure of land disposal facility must ensure protection of any individual inadvertently contacting the waste at any time after active institutional controls are removed.

10 CFR 61.43 - Protection of Individuals During Operations

- Land disposal facility operations must be conducted in compliance with radiation standards of 10 CFR 20 except for radioactivity releases, which shall be governed by 10 CFR 61.41.

- Radiation exposures shall be maintained ALARA.

10 CFR 61.44 - Stability of the Disposal Site After Closure

- Disposal facility shall be sited, designed, operated, and closed to achieve long-term stability and to eliminate, as practicable, the need for ongoing maintenance following closure.

10 CFR 61.53 - Environmental Monitoring

- At time of license application, applicant shall have conducted a 1-year preoperational monitoring program to provide basic disposal site characteristics on the ecology, meteorology, climate, hydrology, geology, geochemistry, and seismology.

- Licensee must have plans for taking corrective measures if migration of radionuclides indicates performance objectives in 10 CFR 61.40 through 61.44 may not be met.

- Licensee shall maintain a monitoring program during disposal facility site construction and operation to evaluate potential health and environmental impacts, long-term effects, and the need for mitigative measures.

- Monitoring system must be capable of providing early warning of releases of radionuclides before they leave the site boundary.

- After site closure, site surveillance shall include a monitoring system based on operating history and site stabilization.

- Post-closure monitoring system must be capable of providing early warning of releases of radionuclides before they leave the site boundary.

10 CFR 61.70 - Scope

- Describes the mechanisms through which the NRC will implement a state or tribal government request to review an applicant's proposed environmental monitoring program.

10 CFR 61.80 - Maintenance of Records, Reports, and Transfers

- Provides specific requirements for submission of annual reports to the NRC, including the results of the environmental monitoring program.

6.1.2 10 CFR 20 - Standards for Protection Against Radiation

The paragraphs in this section summarize the requirements from 10 CFR 20 that pertain to environmental monitoring. A license application must include each of these items.

10 CFR 20.105 - Permissible Levels of Radiation in Unrestricted Areas

- Applications must include anticipated average radiation levels and anticipated occupancy times for each unrestricted area.

- Dose limits are <0.5 rem/calendar year; 2 mrem/hr or 100 mrem/7 days.

10 CFR 20.106 - Radioactivity in Effluents to Unrestricted Areas

- Radioactive effluents must not exceed Appendix B, Table II concentrations averaged over 1 year.

- Appendix B, Table II concentration limits apply at boundary of restricted area.

- Daily intake of radioactive materials from air, water, or food by an exposed population group, averaged over 1 year, must not exceed dailyintake from continuous exposure to air or water at 1/3 of Appendix B, Table II concentrations.

10 CFR 20.201 - Surveys

- Licensee shall evaluate radiation hazards from production, use, release, disposal, or presence of radioactive materials to comply with regulations of 10 CFR 20.

10 CFR 20.401 - Records Of Surveys, Radiation Monitoring, and Disposal

- Survey records shall be maintained in same units used in 10 CFR 20.
- Surveys records shall be preserved for 2 years.
- Survey records used to evaluate radioactive effluent releases to environment shall be maintained until NRC authorizes their disposition.
- Records may be original, reproduced copy, or authenticated microform.
- Records retention period specified in 10 CFR 20 shall apply unless NRC has granted specific exemption.

10 CFR 20.403 - Notifications of Incidents

- Licensee shall report immediately any events that have caused or have threatened to cause $\geq$25 rems whole body exposure; or the release of radioactive materials which, if averaged over 24 hours, would exceed 5000 times the limits in Appendix B, Table II, of 10 CFR 20.
- Licensee shall report within 24 hours any events that have caused or have threatened to cause $\geq$5 rems whole body exposure; or the release of radioactive materials which, if averaged over 24 hours, would exceed 500 times the limits in Appendix B, Table II, of 10 CFR 20.

10 CFR 20.405 - Reports of Over-Exposures and Excessive Levels and Concentrations

- Licensee shall report in writing, within 30 days, of:
  - Levels of radiation or concentrations of radioactive material in a restricted area in excess of any applicable limit.
  - Levels of radiation or concentrations of radioactive material in an unrestricted area >10 X any applicable limit.
- Report shall describe extent of individual exposure, levels of radiation and concentrations of radioactive material, cause of exposure, and corrective steps taken or planned to avoid recurrence.

6.2 REVIEW CRITERIA SUMMARY

This section provides, in Tables 6.1, 6.2, and 6.3, a summary of the environmental monitoring program review criteria on the regulations in 10 CFR 61 and 10 CFR 20.

TABLE 6.1. Summary of Review Criteria for Preoperational Environmental Monitoring Programs

a. Program Objectives/Management	
Bases	10 CFR 61.53(a)
Corrective action plan	Use of concentration limits (e.g., Table II, Appendix B of 10 CFR 20), control charts, statistical analyses (see Section 3.5) to establish corrective action levels within a corrective action plan
Evaluate environmental variability	10 CFR 61.53(a); minimum program duration 1 year; must sample at least seasonally
Administrative organization	10 CFR 61.11(b); Reg. Guide 8.2
b. Program Content	
Bases	10 CFR 61.13(a); 10 CFR 61.53(a)
Appropriate sampling media	10 CFR 61.13(a); at least air, soil, ground and surface water, plants, and burrowing animals
Appropriate sampling locations	10 CFR 61.12(1)
Adequate detection sensitivities	10 CFR 20 Table II, Appendix B
Quality assurance	10 CFR 61.12(j); Reg. Guide 4.15; draft NUREG-1293 (Pittiglio 1987)
Administrative action levels	10 CFR 61.53(b)

TABLE 6.2. Summary of Review Criteria for Operational Environmental Monitoring Programs

a. Program Objectives/ Management/Content	
Bases	10 CFR 61.13(a) and (c); 10 CFR 61.53(a) and (c)
Administrative organization	10 CFR 61.11(b); Reg. Guide 8.2
Early warning of releases	10 CFR 61.53(c)
Appropriate sampling media	10 CFR 61.13(a); at least air, soil, ground water and vadose zone, surface water, plants, and burrowing animals
Appropriate sampling/measurement locations	10 CFR 61.53(c)
Adequate detection sensitivities	10 CFR 20 Table II, Appendix B
Sampling/measurement frequency	10 CFR 61.13(c); 10 CFR 61.53(a) and (c)
Administrative action levels	10 CFR 61.53(b); plans for taking corrective action if performance objectives (61.40 through 61.43) may be exceeded; upper level ≤25% applicable environmental dose standards
b. Data Reporting	
Immediate NRC notification	24-hr average concentrations >5000 x limits in 10 CFR 20 Table II, App. B
24-hr notification	24-hr average concentrations >500 x limits in 10 CFR 20 Table II, App. B
Records maintenance	10 CFR 61.80; licensee maintain records per license conditions or per other NRC rules, regulations, and orders
Reporting to NRC	10 CFR 61.80(i)(1) and (2); annual reporting of environmental monitoring data by end of first calendar quarter

TABLE 6.3. Summary of Review Criteria for Postoperational Environmental Monitoring Programs

a. Short-Term Phase (5 years)

Bases	10 CFR 61.29; 10 CFR 61.53(d); 10 CFR 20.106
Program duration	10 CFR 61.29; maintained by licensee for 5 years
Early warning of releases	10 CFR 61.53(d)
Appropriate sampling media	10 CFR 61.53(d); at least gases, soil, ground water and vadose zone, surface water, plants, and burrowing animals
Appropriate sampling locations	10 CFR 61.53(d); consistent with operational monitoring program
Adequate detection sensitivities	10 CFR 20 Table II, Appendix B
Administrative action levels	10 CFR 61.53(d); upper level ≤25% of applicable environmental dose standards, lower level for significant (at 95% confidence level) increase above background

b. Long-Term Phase (100 years)

Bases	10 CFR 61.13(d); 10 CFR 61.30 (a)(4); 10 CFR 61.44
Appropriate sampling locations	10 CFR 61.30(a)(4); consistent with short-term phase postoperational monitoring program
Appropriate surveillance activities	10 CFR 61.13(d); erosion, slope failure, settlement, and infiltration
Surveillance frequency	10 CFR 61.44; minimal requirements after site closure; at least annually, or as experience dictates

6.3 ENVIRONMENTAL MONITORING PROGRAM SUMMARY

The environmental monitoring programs for the three types of alternative sites (BGV, EMCB, and AUS) discussed in this document are all expected to be similar, except for the differences that occur as a result of site location, i.e., arid versus humid sites. Each environmental monitoring program should include the sampling and analysis of water collected from various surface sampling points, including the collecting and analyzing of rainfall; monitoring and periodic checks on the ground water, including the vadose zone; the measuring of radioactivity in air, soil, and vegetation; and the placing of dosimeters at strategic locations for direct radiation measurements.

Similarly, the environmental monitoring programs for SLB sites are expected to include the same media as those for the alternative disposal methods. Because of the installed drainage systems, extensive care must be taken to prevent contamination of the ground water by water infiltrating the waste and moving through the collection system into the ground water.

6.4 REFERENCES

Regulatory Guide 4.15 (1979); "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment." U.S. Nuclear Regulatory Commission, Office of Standards Development, Washington, D.C.

Regulatory Guide 8.2 (1973); "Guide for Administrative Practices in Radiation Monitoring." U.S. Atomic Energy Commission, Directorate Office of Regulatory Standards, Washington, D.C.

Pittiglio, C. L., Jr. 1987 (Draft). Quality Assurance Guidance for Low-Level Radioactive Waste Disposal Facility. NUREG-1293, U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Code of Federal Regulations, Title 10, Part 20, (10 CFR 20); "Standards for Protection Against Radiation."

U.S. Code of Federal Regulations, Title 10, Part 61 (10 CFR 61); "Licensing Requirements for Land Disposal of Radioactive Waste."

U.S. Code of Federal Regulations, Title 40, Part 6 (40 CFR 6); "Procedures for Implementing the Requirements of the Council on Environmental Quality on the National Environmental Policy Act (NEPA)."

U.S. Code of Federal Regulations, Title 40, Part 50 (40 CFR 50); "National Primary and Secondary Ambient Air Quality Standards."

U.S. Code of Federal Regulations, Title 40, Part 53 (40 CFR 53); "Ambient Air Monitoring Reference and Equivalent Methods."

U.S. Code of Federal Regulations, Title 40, Part 58 (40 CFR 58); "Ambient Air Quality Surveillance."

U.S. Code of Federal Regulations, Title 40, Part 61 (40 CFR 61); "National Emission Standards for Hazardous Air Pollutants (NESHAPS)."

U.S. Code of Federal Regulations, Title 40, Part 125 (40 CFR 125); "Criteria and Standards for the National Pollutant Discharge Elimination System (NPDES)."

U.S. Code of Federal Regulations, Title 40, Part 141 (40 CFR 141); "National Interim Primary Drinking Water Regulations.

U.S. Code of Federal Regulations, Title 40, Part 143 (40 CFR 143); National Secondary Drinking Water Standards."

7.0 GLOSSARY

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

Background is that level of radioactivity from sources existing without the presence of a low-level waste disposal facility, 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 (low-level waste disposal facility 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 by U.S. Nuclear Regulatory Commission (NRC) regulations (10 CFR 10). Byproduct materials include, principally, activation and fission products (e.g., ^{60}Co, ^{90}Sr, ^{137}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 "parts" (e.g., 10 CFR 20 means Title 10, Part 20), which are further divided into sections.

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).

Disposal Site means the natural physical location at which a disposal facility is developed and operated. It is characterized by such features as its proximity to other human developments, geohydrology, meteorology, adjacent land use patterns, soil density and porosity, and the soil load-bearing capacity.

Disposal Unit means a discrete portion of the disposal site into which waste is placed for disposal. A disposal unit is delimited by the physical boundaries, which also define the extent of the radioactive waste. Such physical boundaries may include floors, walls, roofs, undisturbed earth sides, and cover system.

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 document, 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 manmade devices to contain or limit the movement of waste material (radionuclides) from low-level waste disposal facility. 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 low-level waste disposal facility operations on the surrounding region and to monitor the extent and consequences of potential migration of radioactivity from the burial groundsite. 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 postoperational phases. (In this document, the term "surveillance" is equivalent to the term "monitoring.")

Exposure Pathways are potential routes by which people may be exposed to radionuclides or radiation. In this study, inhalation of radioactive particulate, external exposure from the waste, and ingestion of food products, drinking water, and/or animals containing radionuclides of possible low-level waste disposal facility origin are considered.

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

Ground Water is water that exists below the land surface.

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 that involve the performance of functions by human beings to limit contact between the waste at the low-level waste disposal facility and humans.

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

License means a license issued under the regulations in Chapter I of Title 10 of the Code of Federal Regulations (10 CFR 1; Parts 20, 30, 40, 50, 60, 61, 70). 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-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 Code of Federal Regulations.

LLW does not include:

a. high-level waste, as defined by the U.S. Nuclear Regulatory Commission (NRC); (Appendix F of 10 CFR 50);

b. irradiated nuclear reactor fuel;

c. uranium mill tailings, as defined by the NRC (10 CFR 40);

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 by the NRC; (Sections 20.106 and 20.303 of 10 CFR 20);

f. low-activity bulk solid waste;

g. mixed waste, i.e., radiological and nonradiological (hazardous waste).

Natural Barriers include the natural characteristics of a low-level waste disposal facility site or surface and subsurface composition that serve 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.

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.

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

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 low-level waste disposal facility may be located. A site used for a low-level waste disposal facility includes a boundary and a buffer zone, and the property controlled by the licensee.

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.

Source Material means thorium, natural or depleted uranium, or any combination thereof as defined by the U.S. Nuclear Regulatory Commission (10 CFR 40).

Special Nuclear Material includes plutonium, uranium-233, uranium containing more than the natural abundance of the isotope 235 or any material artificially enriched with the foregoing substances as defined by the U.S. Nuclear Regulatory Commission (10 CFR 70).

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

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 or waste, or more recently as 100 nanocuries of plutonium-239 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.

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.

APPENDIX A

DESIGNING AND IMPLEMENTING

ENVIRONMENTAL MONITORING PROGRAMS

APPENDIX A

DESIGNING AND IMPLEMENTING ENVIRONMENTAL MONITORING PROGRAMS

Environmental monitoring programs for low-level radioactive waste disposal facilities (LLWDFs) are required under the regulations of 10 CFR 61. It is the purpose of this appendix to provide guidance in designing, implementing, and evaluating those environmental monitoring programs to ensure compliance with all applicable environmental regulations. The extent of each environmental monitoring program must be determined on a site-specific basis, and each should be designed to flow smoothly from the preoperational through the postoperational phases of the site's operations.

This appendix is divided into three sections--Program Design and Implementation, Environmental Measurements and Media, and Environmental Monitoring Programs. The first section provides guidance in designing programs around stated objectives, based on the regulations. The second section discusses each of the environmental media expected to be involved in environmental monitoring programs at LLWDFs and provides specific guidance with respect to choosing sampling methods, locations, and analyses. The last section is devoted to a brief summary of suggested numbers of samples and types of analyses for the different media involved. It includes guidance for the preoperational, operational, and postoperational phases, as well as for both arid and humid sites, especially for the operational phase of environmental monitoring programs.

A.1 PROGRAM DESIGN AND IMPLEMENTATION

It is essential that the environmental monitoring programs for LLWDFs be designed in accordance with the requirements and objectives of 10 CFR 61. It is also imperative that the environmental monitoring program be reviewed periodically and modified as program and/or regulatory requirements change. Each review and/or modification should be documented with the subsequent documentation maintained in an Environmental Monitoring Plan and associated environmental surveillance files.

In addition to determining the need for an environmental monitoring program based on the regulatory requirements of 10 CFR 61 and the specific objectives noted in Sections 1.4, 3.1, 4.1, and 5.1 of this document, certain subsidiary objectives should also be considered. For example, site history and current public interests may indicate the need for an environmental monitoring program that examines specific aspects of the site's environmental impact, even when no other need is indicated. The following is a partial list of subsidiary objectives, as provided in ICRP Publication 43 (ICRP 1985), that should be considered when establishing site-specific environmental monitoring program objectives:

- The environmental monitoring program should provide information to the public.

- The program should distinguish site radiation contributions from other local sources (natural or manmade).

- The program should obtain data that may be required in assessment of the consequences of an accident.

- The program should identify changes in relative importance of transfer parameters.

The quality assessment samples and measurements taken specifically as part of the site's quality assurance program should be integrated with the routine monitoring program, not only for greater efficiency but also to ensure relevant results.

To ensure continuity and consistency of data collected within the environmental monitoring program, new techniques and locations included in the program should be designed to incorporate sufficient overlapping of data.

Provisions for environmental monitoring during an emergency situation should be considered when determining routine program needs. Emergency environmental monitoring systems and procedures should be specified in the emergency response plan in effect for the site.

A.1.1 Program Planning and Design

Factors that affect the relative level of environmental monitoring, and to some extent the points at which measurements are to be made, include:

- the potential hazard of the materials disposed, considering both expected quantities and relative radiotoxicities

- the extent to which facility operations are routine and unchanging

- the need for supplementing and complementing effluent monitoring

- the size and distribution of the exposed population

- the cost effectiveness of modifications to the environmental monitoring program

- the availability of measurement techniques that provide sufficiently sensitive comparisons with the applicable standard and "background" measurements.

A simplified flow diagram is provided in Figure A.1 to show the relationship of the needed data input and the associated environmental pathway analysis procedures to environmental monitoring program planning. Because the basic radiation standards are given in terms of dose equivalent

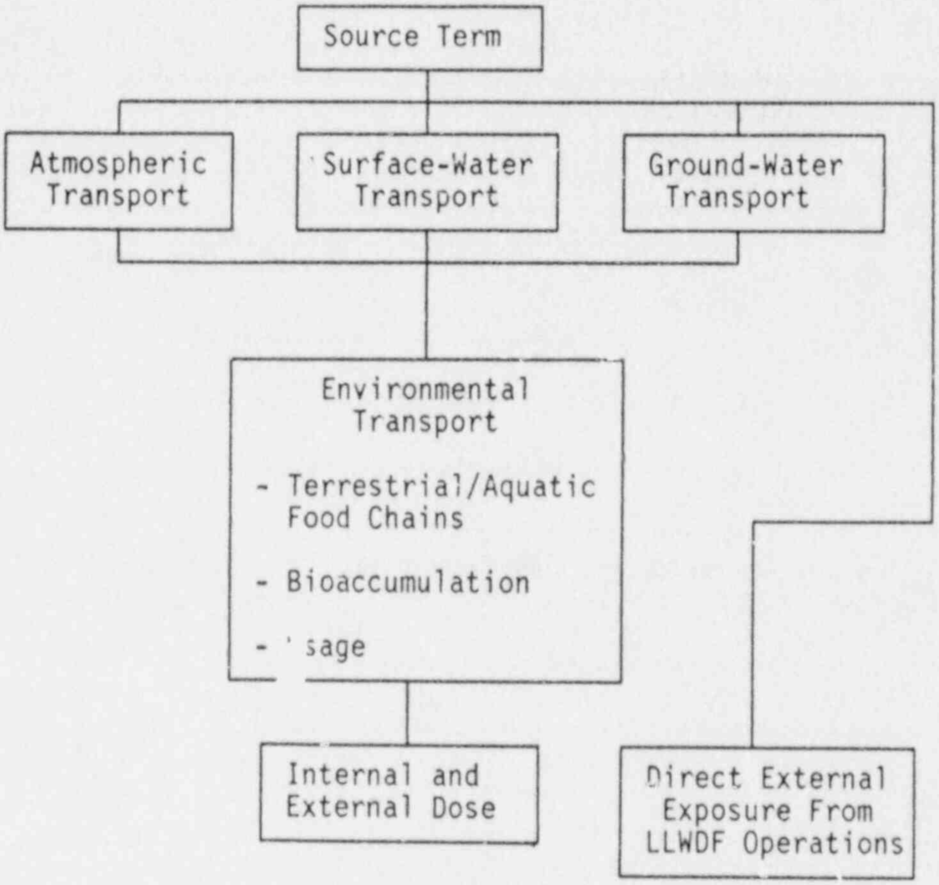


FIGURE A.1. Flow Diagram of Data Input and Environmental Pathway Analysis Procedures

or effective dose equivalent to people, the environmental monitoring program planning process should address the sampling or direct measurement of critical[(a)] environmental pathways that may contribute to the radiation exposure of the public. The environmental monitoring media sampled or radiation measurements made should represent, as much as possible, the actual exposure vectors to people. Selection of locations, frequency, media and radionuclides to be measured, and measurement methods to be used are the basic requirements for an environmental monitoring program.

To these basic requirements should be added any special monitoring requirements, such as trend indicators and additional sample/measurements required for quality assurance. Criteria for selection of samples and

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(a) "Critical" path is defined according to standard usage as the pathway (nuclide, organ, population group) providing the largest percentage of the applicable dose criterion.

measurements should be documented so that the purpose and any limitations on interpretations of results will be clear.

A.1.1.1 Critical Pathway Analysis

A summary of the essential elements for critical pathway analyses are provided below:

- site-specific source terms (radionuclides, quantities, and potential effluent pathways)
- local meteorology and site topography
- surface- and ground-water hydrology
- local demography (population distribution, land and water use, recreational habits, diet).

Potential effluent releases, combined with dispersion calculations based on meteorologic and hydrologic data, should be used to estimate air and water concentrations at the points of interest. Using appropriate dose/intake factors, the annual doses from each pathway and each radionuclide should be determined. If local data are not available, common default parameters should 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.

A.1.1.2 Effluent Pathways and Radionuclides

The effluents and the environment into which they are dispersed are dynamic, exhibiting both spatial and temporal variations of nearly all constituents. The importance of each individual radionuclide depends on its physical and chemical form, which determines its movement in the environment and eventual uptake, deposition, and retention by humans, and on the differential metabolism of the radionuclide by humans.

Table 6 of Denham (1979) and Table 3.1 of Corley et al. (1981), present the relative importance of sampling specific environmental radionuclide/medium combinations for a normalized release of the given radionuclide(s) via each effluent pathway. To account for the dynamic nature of effluents and environmental conditions at each site, the format of the referenced tables can be used to establish a realistic radionuclide and environmental medium combination to be incorporated in a site's environmental monitoring program. All site-specific information and resulting decisions should be documented in the site environmental monitoring files.

Table 4 of Section 7 of the Health Physics Society Committee Report, Upgrading Environmental Radiation Data (Watson 1980), provides guidance on the minimum number of sampling/measurement locations for environmental monitoring programs. Although the values presented in that report are not directly applicable here, the methodology of using critical pathway analyses to determine minimum numbers of sampling/measurement stations is. Providing site-specific tables of the minimum number of environmental sampling/measurement locations per site as a function of calculated annual effective dose equivalent to the maximally exposed offsite individual or critical population group is recommended. These values chosen, following a site-specific environmental assessment, should be documented in the environmental monitoring files.

The approach in Watson (1980) is to establish a level at which the minimum number of samples (e.g., one control and one indicator) would be required. For a dose-based system, the Watson (1980) reference suggests grouping environmental media into two basic categories: air and ambient radiation, and water and foodstuffs. The minimum numbers of samples are assumed to differ by a factor of two for the two categories; the air and ambient radiation media are deemed to require the greater number of samples or measurements. Once the minimum levels are established, then for each increase in projected dose equivalent by an order of magnitude, the number of sampling/measurement locations is increased by a factor of three or by a factor of 10 for each factor of 100 increase in the dose equivalent. The number of sampling locations for other media, such as soil and sediment, which are not part of a direct exposure pathway, should be considered at the same relative levels as for air (soil) and water (sediment), respectively.

A.2 ENVIRONMENTAL MEASUREMENTS AND MEDIA

This section provides a discussion of good monitoring practices for each of the radiological measurement/monitoring activities expected to be included in the environmental monitoring programs at LLWDFs. The section is further subdivided for each measurement/sampling medium into separate discussions of the basis for monitoring, locations (including placement criteria, when available or applicable), frequency of sampling/measurement, sampling methods and criteria, and sampling/analytical precautions. Several references are available that should be used as guidance in establishing environmental monitoring programs at LLWDFs [Regulatory Guide 4.1; NRC 1988 (draft); NCRP 1985; Sedlet and Wynveen 1983; and Corley et al. 1981].

A.2.1 External Radiation

The basis for the performance of external radiation monitoring, along with the associated measurement location and frequency requirements, are discussed in the following subsections.

A.2.1.1 Basis for Monitoring

The extent of each environmental monitoring program should be based on applicable regulations, hazard potential, quantities and concentrations of materials released (or expected to be released for those facilities not yet in operation). A primary objective is to assess the actual or potential radiation dose to persons in the site environs.

For most LLWDFs, the whole-body (or gonads) exposure will be limiting, and penetrating radiation measurements are satisfactory. Exceptions may be the atmospheric release of any beta-emitters such as uranium or ^{85}Kr. The gamma exposure (or exposure-rate) should be measured or calculated; any significant skin dose from airborne beta-emitters should be calculated from projected effluent data. If external beta doses from deposition are considered to be significant, they should be estimated from effluent data, beta-sensitive dosimeters, or by soil sampling and laboratory analysis.

A.2.1.2 Measurement Locations and Frequency

Considerable judgment must be used in locating environmental radiation measurement stations. Before final placement of any environmental radiation measurement station (background or control and indicator locations), an initial on-the-spot survey should be performed and documented to determine the absence of possible naturally occurring anomalies that may affect interpretation of later measurements. Measurement locations, so selected for the routine environmental monitoring program, should be well documented. The recommended technique for making these pre-surveys is to use a low-level radiation survey instrument (e.g., micro-R meter) followed up with a pressurized ion chamber (PIC) measurement at those geographic locations selected on the basis of the preliminary screening by portable instrument survey. If desired, an in situ gamma-ray spectrometer [NaI, IGe, or Ge(Li)] can be used to determine which terrestrial nuclides are contributing to the observed exposure rate. Examples of dosimeter placement locations to be avoided, if at all possible, include the following:

- locations where the geology differs from the norm (i.e., changes in the terrestrial component)
- locations where the altitude differs significantly; e.g., altitudinal differences between "background" or control locations and those indicator locations to be used around a given site should not exceed 150 m in elevation (changes in the cosmic component)
- locations where the proximity of structures could alter the measurement results (changes from shielding or radiation enhancement effects from building materials)
- valleys or hollows (where puddling of precipitation or runoff could accumulate, or where local topography could shield the dosimeters from the possible passage of atmospheric effluents).

Selection of the indicator locations should be based on expected sources of external radiation--soil-deposited atmospheric particulates released from the site, any large radiation sources, or potential routes of waste transport from the site--as well as the local population distribution. The technique described by Waite (1973a,b) for placement of air samplers, based on average meteorological conditions and existing population distributions, should be considered for determining external radiation measurement locations.

Background or control measurement stations should be located a minimum distance of 15 to 20 km from the site in the least prevalent wind direction. Control stations should also be placed in areas typical of local geology, away from buildings (which can shield the detectors), and at similar elevations to those for indicator stations. The emphasis here is on the placement of dosimeter stations such that the difference between background/control or preoperational data and the data from those stations expected to be affected by site activities can accurately be assessed.

Offsite radiation measurement locations should include a background or control location, site perimeter or boundary locations, and locations in nearby communities (within a 15-km radius of the site). The site perimeter or boundary locations should coincide with the maximum predicted ground-level concentration from atmospheric releases, averaged over a period of one year, where any member of the public resides or abides. For those sites larger than a few kilometers in radius, the maximum predicted concentrations may actually be onsite. In this case, onsite radiation measurements should also be made to include the location of predicted maximum air concentration(s), as well as other locations needed to help interpret the offsite results.

The recommended height for external radiation measurement is 1 m[a] above the surface. If another height is used, the relationship to the 1-m height should be established and documented for the site. The frequency should be based on predicted exposure rates from site operations at the measurement locations. Integrating devices (e.g., dosimeters) should be exposed long enough (typically 1 calendar quarter) to produce a readily detectable dose (e.g., 10 x the minimum sensitivity of the dosimeter; for TLDs this would represent an exposure on the order of 5 to 10 mR). If intermittent external radiation measurements are made, their frequency should be timed to coincide with batch atmospheric releases or the intermittent use of large sources or the operation of radiation-generating machines.

A.2.1.3 Direct Radiation Measurement

Instruments that have application to environmental monitoring programs include Geiger-Müller and gamma scintillation systems, pressurized ion chambers (PIC), and thermoluminescent dosimeters (TLD). The method of measurement should depend on the anticipated type of radiation; for beta and gamma radiation, the method of measurement should be accurate to within ±30%. Guidance for the use of Geiger Müller detectors is provided in Regulatory Guide 8.6.

If real-time external radiation measurements are desired, then direct radiation measurements should be made using either integrating or rate devices with continuous recording. Continuous environmental gamma-ray monitoring is available (Urabe and Katsurayama 1984, Jackson et al. 1985) and highly desirable, yet it cannot always be justified on the basis of initial system cost or long-term maintenance. However, in situ gamma spectrometry

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(a) Approximately the height of the gonads in adults standing or walking.

should be used as a method of documenting environmental radioactivity resulting from natural and manmade sources (e.g., for dosimeter placement). The deployment of at least one continuously recording exposure-rate instrument is recommended, preferably near the site boundary, to provide detection and approximate magnitude of sudden changes in ambient radiation levels.

Several materials have been identified as suitable for use in environmental TLDs including LiF, CaF_2, and $CaSO_4$ (Gesell 1982). References describing the various TLDs commonly used for environmental monitoring include Hall and LaRocca (1966); Hendee (1967); Mejdahl (1970); Hoy (1971); dePlanque (1972); Fix and Miller (1978); and dePlanque and Gesell (1982). NRC Regulatory Guide 4.13 should be used for performance testing, procedural specifications, and correction techniques for TLDs. Annealing, calibration, readout, storage, and exposure periods used should be consistent with the ANSI standard (ANSI 1975) recommendations.

Where integrating dosimeters are used, three or more dosimeters should be provided at each location (if possible in the same package). Integrating dosimeters should be read without undue delay, but, above all, at a consistent time following collection. Only if adequate precautions are taken to avoid recording a significant exposure in transit should integrating dosimeters be sent to a distant location for processing.

Sites are encouraged to participate in international intercomparison studies, such as the ones reported in dePlanque et al. (1976) and Gesell et al. (1982). Calibration of dosimeters and exposure-rate instruments should be based on either National Bureau of Standards (NBS) certified sources or on exposure rates measured with R-meters (or equivalent) that have been calibrated by NBS. The most commonly used sources are ^{137}Cs and ^{60}Co.

A.2.2 Air

The basis for performing environmental air sampling and the requirements associated with air sampling methods, criteria, locations, and frequencies are presented in the following subsections.

A.2.2.1 Basis for Sampling

Because air is a primary exposure pathway to humans from radionuclides released to the atmosphere, environmental air sampling should be conducted to evaluate potential doses to environmental populations from inhaled or ingested radionuclides or from external radiation. The inhalation of airborne radionuclides, coming either directly from the waste or from resuspension following contamination spreads, may result in their absorption from the lung or GI tract. Transpiration through the skin may also result in human exposure. The categories of airborne radionuclides that should be considered for measurement include particulates, gases and vapors.

Particulates. Radioactive materials in particulate form can result in radiation exposures to individuals both by direct inhalation and by deposition on soil and vegetation. Although particulate sizes range across a broad spectrum. from diameters of about 0.01 μm to 10 μm, the optimum size for deposition in the upper respiratory tract and subsequently the deep lung, tends to be on the low end of the size spectrum (i.e., from 0.01 to 3 μm), with 1 μm often used as the appropriate size for dose assessment. However, particulate filters used for sampling will function over the entire size spectrum, collecting particulates in the "respirable" range, as well as those that are not. If releases of particulate materials could contribute significantly to environmental doses, measurements of particle size should be made.

Depending on the projected environmental doses, a variety of analyses, ranging from gamma and alpha spectroscopy to specific radionuclide analyses, can be performed and used as input information for the dose model.

Gases and Vapors. This category includes noble gases, tritium, and carbon-14 that can provide exposure to individuals by external radiation (noble gases), inhalation, and skin absorption (tritium). The external radiation portion of the potential exposure from these sources is most often accounted for through the ambient radiation measurements, while the potential exposures from inhalation and skin absorption must be accounted for through sampling and subsequent analyses. Tritium and carbon-14 are collected on cartridges (silica gel for tritiated water, HTO, and soda lime for carbon-14 dioxide), while noble gases can be collected by compression or cryogenic techniques. All three are analyzed by liquid scintillation counting techniques, following removal of the vapor or gas from the respective collection devices.

A.2.2.2 Locations

Air sampling locations should be selected to represent radionuclide concentrations breathed by the population surrounding the LLWDF. Selection of background sampling and measurement locations for air must be made with special care. For measurements to be compared with the effects of airborne releases, a minimum distance of 15 to 20 km from the release point in the least prevalent wind direction is suggested.

Number of Locations. Air sample locations should include: a background or control location; locations of maximum predicted ground-level concentration from potential operational or off-normal releases, averaged over a period of one year where any member of the public resides or abides; and locations in the nearest community within a 15-km radius of the site. For those sites larger than a few kilometers in radius, the maximum predicted concentrations may actually be onsite. In this case, onsite sampling should include the locations of predicted maximum concentration(s) and any other locations needed to help interpret the offsite sample results.

The exact number of samplers will be determined by meteorology, demography, and the magnitude of projected doses to the surrounding population. If the maximally exposed individual could receive an annual dose equivalent of more than 5 mrem, additional air samples should be collected in those communities within a 15-km radius of the site boundary for which the projected dose equivalents are highest and at a control location, 15 to 30 km from the site in the least prevalent wind direction.

Placement Criteria. Air samples should be collected at a height of 1.5 m above ground level (approximately the height of inhalation for adults), in a location free from unusual micrometeorological or other conditions (e.g., in proximity of a large building, vehicular traffic) that could result in artificially high or low concentrations. Locations should be selected to avoid areas where large-particle (nonrespirable) fugitive dusts can dominate the sample (Ludwig 1976). The station should be protected from the weather and should be housed in a locked facility to afford a measure of security from tampering.

It is suggested that a method similar to that developed by Waite (1973b) be used to determine the number of air sampling stations and their placement. Waite's method entails examining demographic and meteorologic data for the site to determine the distance to local population centers, their population, and the wind frequency distribution and weighting factors that are scaled to equal the desired number of sampling locations. The application of this method to sites in agricultural areas requires only minor modification of the procedure illustrated. For agricultural areas, an equivalent population index is derived by multiplying the number of people who are direct recipients of produce, dairy and meat products from the area by the biological discrimination factor for the critical nuclide in the exposure pathway involved.

A.2.2.3 Sampling Frequency

In general, the frequency of collection for air samples is adjusted to take into account sample-collector limitations, air mover capabilities, and the physical problem of retrieving samples from each location on a fixed frequency, typically 1 to 2 wk. Experience has shown that sampling rates of 30 to 120 L/min can be used with moderate power requirements and acceptable dust loading for air particulate filters changed on this basis.

The common practice, especially for the longer-lived radionuclides, has been to composite filters for subsequent analysis from several locations and/or successive time periods, taking advantage of the larger volume of air sampled to achieve the desired sensitivity. Use of compositing techniques implies that the concentration of a given radionuclide at the locations or for the time composited is sufficiently constant for the end use of the data. For dose calculation purposes, this practice is deemed acceptable; the annual average concentration for a location or for a group of locations can still be compared against an annual average for a background location as an indication of potential facility impact during the year in which the samples were obtained. Comparison of annual averages to the standards (mrem/year) is appropriate. Also, averages for successive years can be compared for detection of general trends. However, compositing does not permit a ready correlation of environmental concentrations with the releases from a given trench or area of the site nor a reliable indication of an unusual release (because of dilution with potentially uncontaminated samples).

For air sampling of non-particulates, the available tradeoff between sensitivity and frequency of sample removal is governed primarily by the fact that "breakthrough" can occur with the respective cartridges (e.g., silica gel, molecular sieves, and soda lime) used for gas and vapor collection. These breakthrough phenomena can be based on flow rate, total volume, activity, or a combination of these. The sample exchange frequency for non-particulate air sampling should be determined on a site-specific basis and should be documented in the environmental monitoring files.

A.2.2.4 Sampling Methods and Criteria

Sampling media and devices used to measure contaminants in the media are discussed in the following sections.

Particulates. Filtration is by far the most popular air sampling method (Alpha 1972) and the method generally required for total air particulate collection at a site. Particulate filters can be made of any fibrous material, and a variety of filter media (e.g., cellulose, glass fiber, membrane, polystyrene) are commercially available. No single filter type is best for all purposes, but the specific filter to be used should be selected to meet site-specific requirements such as high collection efficiency, particle-size selectivity, retention of alpha-emitters on the filter surface, or the ease of radiochemical analysis. The choice of filter or filters and reasons for the choice should be documented in the site environmental monitoring files. Any filter media used should retain a minimum of 99% of dioctyl phthalate (DOP) particles with an aerodynamic mean diameter of 0.3 μm at the air face velocity and pressure drop expected in use (American Conference of Governmental Industrial Hygienists 1974).

Noble Gases. For noble gases, the collection of an air sample by compression or cryogenic techniques, separation and purification by adsorption on chromatographic columns, and analysis by liquid scintillation counting is the suggested technique (Trevethan and Price 1985; Grossman and Holloway 1985). Other methods for radioactive gas sampling, either grab or continuous, can be found in Noble Gases (Stanley and Moghissi 1975). Atmospheric stability and wind speed and direction during the period in which the samples were collected should be recorded to aid in interpreting and using the data.

Tritium. Several methods are available for collection of atmospheric tritium, such as bubblers, molecular sieves, and silica gel (Brown et al. 1978; Corley et al. 1981). The method of the Intersociety Committee (APHA 1972) recommends the use of silica gel as a desiccant to remove moisture (H_2O, HTO) from air, followed by re-evolution, collection as a liquid, and liquid scintillation counting. This procedure calls for a 30-cm-long by 3-cm-diameter cylinder filled with silica gel (180 g). Air is pumped at a flow rate of 100 to 150 cm^3/min through the silica gel column, which collects essentially all of the moisture; the distillate is collected and counted using standard liquid scintillation techniques. Tritium gas (HT) is totally excluded by this procedure.

Where intermittent sampling of HTO only for short time periods (less than 30 min) is essential for a given site, the method of Osborne (1974) can be used. In this approach, tritiated water vapor (HTO) is removed from the air by bubbling moist air through a gas washing bottle. Measurement of the specific activity of tritium in atmospheric moisture, using a passive device such as a container of silica gel suspended in air to collect tritiated water vapor, is considered satisfactory as a detection device only.

A.2.2.5 Precautions

A number of precautions should be taken when using the referenced methods and equipment for air sampling in the environment. Some of these relate to general air sampling and some relate specifically to the sampling of particulates, radioiodines, noble gases, or tritium:

- Sufficient material needs to be obtained for analysis of samples in the time frame set to meet reporting and data retrieval requirements. The requirements of sufficient volume of air and number of samples should be evaluated and the need for compositing samples considered (Corley et al. 1981).

- Excessive material (sample or dust) collected on filters can invalidate the sample in several ways: the flow rate through the filter may be unknown, the pump may fail, the particulate material may penetrate the filter, the analysis for alpha-emitters may be affected, or material on the surface may be lost when the flow is interrupted (Corley et al. 1981).

- Excessive sampling velocity can invalidate the sample if too much sample is collected during a specific time period.

- Collection efficiency of an air filter is affected by flow rate; too low an air sampling velocity can produce a reduced collection efficiency for specific filters (Bellamy 1974).

- Ambient levels of radon and thoron and their daughter products can affect the analysis of a number of filter samples. These naturally occurring radon and thoron daughters are found on air particulate filters because they adhere to particulate matter and are thus efficiently trapped by the air sampling filter. Therefore, any measurement system for other alpha and/or beta emitters (e.g., ^{239}Pu, ^{90}Sr), must be able to discriminate against the typically much larger "background." The most common method of discrimination is to retain the filter from 1 to 7 days (American Conference of Governmental Industrial Hygienists 1974) after collection and prior to counting, to allow for decay of the short-lived radon and thoron daughters.

A.2.2.6 Operational Criteria

The following operational criteria relate to environmental sampling instrumentation and methods:

- The system should be designed to take a "representative" sample of the ambient air on a continuous basis (ANSI 1969, NRC 1974, ISO 1975). The preferred sampling height is 1.5 m[(a)] above ground level, in a location free from unusual micrometeorological or other conditions (e.g., proximity of large buildings, vehicular traffic) that could result in artificially high or low air concentrations.

- The linear flow rate across particulate filters and charcoal cartridges should be maintained between 20 and 50 m/min (Corley et al. 1981).

- A fixed sampling rate should be used, constant to within ±20% during normal operation and expected filter-loading. Total air flow or total running time should be indicated.

- The assembled sampling system should be leak-tested and flow-calibrated in the field.

- The entire system should be inspected and tested at least quarterly and recalibrated and maintained when indicated. Less frequent inspection and test requirements may be warranted if the reliability and accuracy of the system can be documented.

- The air sampling system should be protected from the weather, and should be housed in a locked facility to afford a measure of security from accidental or willful damage or tampering.

- Air sampling devices, such as "quick-disconnect" filter holders, should be designed so that the potential for loss of sample during the collection process is minimized.

A.2.2.7 <u>Performance Criteria</u>

For environmental air samples, however, note that the volume of air pumped may not be known more precisely than ±10%. Therefore, there may be little merit in incurring significant costs to make the counting procedure much more precise than the air volume precision. Regulatory Guide 8.25 contains guidance relative to determining errors associated with the total volume of air sampled.

A.2.3 <u>Vegetation and Other Biota</u>

The basis and procedural requirements for sampling of the various terrestrial vegetation and other biota (e.g., native vegetation as well as food stuffs for human consumption) are provided in the following subsections.

(a) Approximately the height of inhalation for adults standing or walking.

A.2.3.1 Basis for Sampling

A preliminary pathway analysis should be performed and documented to determine which terrestrial foods, if any, must be sampled to obtain data necessary for assessing radiation doses to the public. If the preliminary analysis indicates that the annual effective dose equivalent from ingestion of terrestrial foods is 5 mrem or greater, then sufficient sampling and analysis should be carried out to ensure that the foods and radionuclides contributing at least 90% of this ingestion dose are evaluated. If the annual effective dose equivalent is between 1 and 5 mrem, then sufficient sampling and analysis should be carried out to provide reasonable insurance that the doses are in this range. When the annual effective dose equivalent is projected to be less than 1 mrem, then annual sampling and analysis of indicator materials, such as soil or vegetation, should be performed to determine if there is measurable long-term buildup of radionuclides in the terrestrial environment. Such long-term buildup could affect the relative contributions of certain radionuclides and foods to the total radiation dose of site origin.

Radionuclides with long half-lives may accumulate in the soil from multi-year chronic releases to the atmosphere or to waters used for irrigation. However, the availability of these radionuclides to plants grown in such soil may decrease with time as a result of several natural processes. These processes include: changes in chemical or physical form of the radionuclides caused by weathering or the action of soil bacteria, and fixation onto soil materials or the litter layer. Other processes actually lower the concentration of the radionuclides at the places of interest. These latter processes include: migration below the root zone of the plant with irrigation water or rainfall, removal of contaminated soil by wind or water erosion, or cultivation.

It is also possible that changes in chemical and physical form might, in some instances, increase the relative uptake by vegetation; and fixation, by preventing migration away from the root zone, might increase the uptake by vegetation.

Foods to be considered in the pathway analysis, listed in approximate order of importance, are milk, vegetables, meat, eggs, grain, and fruit. If wild game, such as deer or game birds, are available locally, then these should also be considered in the pathway analysis.

A.2.3.2 Agricultural Products

Representative samples of the pathway-significant agricultural products grown within 16 km of the site should be collected and analyzed for radionuclides potentially present from site operations. These should be collected at two locations: the place of expected maximum radionuclide concentrations, and a "background" location unlikely to be affected by radionuclides released from the site. Fresh produce, meat, poultry, and eggs can be purchased from local farmers or from commercial outlets if the origin can be identified. The origin of all agricultural samples should be documented.

Milk. Cow's milk and, in certain localities, goat's milk, is widely consumed by all age groups. Therefore, milk is frequently sampled in the environs of LLWDFs, if dairy animals are pastured near the site. If dairy herds or "family" cows (or goats) are present in the vicinity of the site (within 16 km), representative milk samples should be taken and analyzed for radionuclides potentially present from site operations. The frequency of sampling will depend on the magnitude of the radiation doses potentially received via this source; the particular radionuclides released from the facility; and the variability of the radionuclide release rates. Radionuclides of potential significance in milk include ^{89}Sr, ^{90}Sr, ^{129}I, ^{137}Cs, and ^{226}Ra.

The number of locations to be sampled depends on the number and distribution of the dairy herds or family cows in the vicinity (16 km) of the site, but a minimum of one background and one potentially affected location should be sampled at least annually. For ^{90}Sr, ^{129}I, and ^{137}Cs, quarterly composite samples are usually adequate. All decisions on sampling frequencies and locations and the reasons behind them should be documented.

Milk samples should be as representative as possible of the location of interest. Commercially available processed milk, while representative of consumption by the general public, may not have been produced in the local area. Raw milk should be sampled for evaluation of potential radiation doses to individuals consuming milk produced by a family cow.

No particular sampling techniques are required, other than to guard against cross-contamination and souring or curdling of the milk. For the levels of contamination expected at most sites, a 4-L sample is necessary to achieve the required detection level. However, for goat's milk, a 1-L sample may be all that can be obtained, especially from a single goat. Liquid milk samples should be refrigerated or otherwise preserved prior to analysis; however, the analytical procedure to be used should be considered when choosing a sample preservation method. Radioanalysis of milk usually involves ion-exchange techniques (for concentration) followed by beta or gamma counting.

Analytical results of leafy vegetable (or fresh forage) samples can be used to estimate concentrations in milk using transfer coefficients or concentration ratios for dose calculations when fresh milk is not available.

Vegetation. Collection and analysis of vegetation samples can serve three useful purposes: evaluating the potential radiation doses received by people consuming such vegetation (i.e., vegetables); predicting the possible concentrations in meat, eggs, and milk from animals consuming contaminated forage (and resultant radiation doses to consumers of the animal products); and monitoring trends in environmental contamination and possible long-term accumulation of radionuclides. Regulatory Guide 4.6 provides guidance in sampling and analyzing environmental media for strontium.

Radionuclides of interest in vegetation include those listed previously for milk (^{3}H, ^{89}Sr, ^{90}Sr, ^{129}I, and ^{137}Cs) and possibly ^{106}Ru. Several kilograms of vegetation may be needed to provide a sufficient sample for analysis, depending on the analytical sensitivities for the radionuclides of interest. The particular samples collected will depend on species availability, seasonal growth patterns, farming practices and the reasons for sample collection. Where actual measurement of radioactivity cannot be made (e.g., radioactivity levels below minimum detectable concentrations), dose calculations should include estimates of potential contributions.

Vegetables. If the samples are being collected for evaluation of radiation doses to people, then the edible portions of fresh vegetables should be analyzed for the radionuclides of interest. Analysis may include direct gamma measurement, or alpha or beta counting after drying, ashing, and/or chemical separation of the desired radionuclide. In either case, the results should be expressed in terms of the radionuclide concentrations in the vegetables (consumed state) used in the dose calculation (e.g., fresh weight, peeled weight, etc.).

Samples of vegetables should be collected at local farms or from family gardens when the effective dose equivalent to individuals is being evaluated. It is important that the origin of the materials sampled be within a 10- to 15-km radius of the site and be identified. Analyses of commercial food items of known origin can also provide data on concentrations of naturally occurring or fallout radionuclides.

Forage. Samples collected for evaluation of intake of radionuclides by farm animals should be representative of the vegetation consumed by the animals. This includes silage and hay as well as fresh forage when available. Samples collected for monitoring of long-term trends in environmental contamination should be capable of accumulating the radionuclides of interest to permit detection at the desired level. Such samples should be collected from the locations of interest, including, but not necessarily limited to, a "background" location and a "maximum" location.

A.2.3.3 Game Animals

At some sites, animals such as deer, rabbits, and game birds are components of the diets of certain individuals. A review of the hunting habits in the local area should be included in the preliminary pathway analysis to determine if such game are important parts of the diet of the local population or of hunters from outside of the region. If the results of the preliminary survey indicate that local game could make an important dose contribution, then a more detailed survey of the amounts of each type of game harvested and the disposition of the meat should be made and documented. State and local game officials should be consulted when selecting the appropriate species to sample.

It is also important to determine if the meat is eaten, and if so, whether it is eaten fresh or frozen or given to others. If the results of the preliminary survey indicate that this pathway contributes an effective dose equivalent of less than 1 mrem/yr, then annual sampling and analysis of two or three representative species will be sufficient to determine whether or not this pathway is still insignificant.

Radionuclides of interest in wild game or burrowing species are similar to those listed under the discussion of milk: ^{14}C, ^{90}Sr, ^{137}Cs, and possibly ^{129}I. One to two kilogram samples should be collected to allow sufficient quantity for analysis.

Wild game samples can be obtained from wildlife that is trapped, acquired by hunters, or collected after accidental road kills, or the samples can be obtained from an appropriate state agency. Wildlife that is relatively rare locally should not be taken as environmental samples. When sampling deer and other game animals, it is important not to contaminate the meat sample with radionuclides that may be present on the animal's fur or in its gut.

A.2.4 Soil

The basis for performing environmental soil sampling and the requirements associated with soil sampling methods, locations, and frequencies are presented in the following subsections.

A.2.4.1 Basis for Sampling

Soil provides an integrating medium that can account for contaminants released to the atmosphere, either directly in gaseous effluents or indirectly from resuspension of onsite contamination, or through liquid effluents released to a stream that is subsequently used for irrigation. Hence, soil sampling and analysis should be used to evaluate the long-term accumulation trends and to estimate environmental radionuclide inventories.

In addition to site-specific radionuclides, naturally occurring (e.g., uranium and thorium series and ^{7}Be) and fallout radionuclides can be expected in soil samples. The relative importance of these contributors is primarily dependent on site operations as well as site geography, geology, and meteorology.

Radionuclides that are often detected in soil samples include ^{60}Co, ^{90}Sr, ^{95}Zr-Nb, ^{106}Ru, ^{144}Ce-Pr, ^{137}Cs, ^{238}Pu, and ^{239}Pu. The relative abundance of these materials varies with the source and half-life of the materials. Analytical and sample preparation procedures should be tailored to the radionuclides of interest.

Perhaps the greatest diversity among environmental monitoring techniques occurs with sampling and analyzing soil. Part of this diversity arises from different purposes for soil sampling and analysis (e.g., trend evaluation, projection of future plant uptake, contaminant inventory, comparison with applicable standards).

Plutonium is one of the most commonly analyzed contaminants in soil. However, the limitations of sampling and analysis of plutonium in soil are many, as noted in Regulatory Guide 4.5. Although concentrations of plutonium and other radionuclides in soil are generally readily detectable, the determination of their significance in terms of exposure to humans is less readily quantifiable, except perhaps for the gamma emitters, such as ^{60}Co and ^{137}Cs. Therefore, it is desirable to assess, document, and periodically reassess the distribution and fate of radionuclides in soil, especially those radionuclides of possible site origin.

A.2.4.2 Location and Frequency

As with air sampling and direct radiation measurements, soil sampling locations should be determined from pathway analyses and should include selected sampling locations that correspond to the site boundary, points of suspected buildup, the nearest identifiable points of potential individual exposure, and areas of anticipated maximum ground-level concentrations downwind. Background determinations should be based on soil sampling and analysis at points corresponding to background (or control) air sampling locations. Where possible, soil sampling locations should be selected to coincide with air sampling stations, since the comparability of data may be important in achieving the objectives of the overall environmental monitoring program.

Except where the purpose of the soil sampling dictates otherwise, every effort should be made to avoid tilled areas or areas of unusual wind or precipitation influence when selecting soil sampling locations. An annual sampling frequency is recommended for long-term accumulation trends. The sampling frequency of soil collected for purposes other than long-term environmental accumulation should be based on site-specific purposes and radionuclide half-life, with the purpose(s) and details documented.

A.2.4.3 Sampling Methods

Several references are available that should be used as guidance in sampling, preparing, and analyzing soil for plutonium (Fowler et al. 1971; Sill and Williams 1971; AEC 1974), for radium (Myrick et al. 1983; Fleischhauer 1984; Meyer and Purvis 1985), and for other radionuclides (Mohrand and Franks 1982; ASTM 1986a). In addition, Healy (1984) has proposed a standard for comparing observed to allowable concentrations of plutonium.

It is recommended that trends in local environmental radionuclide levels be determined through routine soil sampling. Surface-soil sampling should be conducted according to the methods of NRC Regulatory Guide 4.5, ASTM (1986a), or HASL 300 (Harley 1986).

Profile depths need to be established; ASTM C998-83 (ASTM 1986a) recommends profile depths of 30 cm to measure the total amount of a radionuclide deposited on the soil during preoperational assessment, periodically as needed, and after a disturbance of the soil.

Useful information about soil contamination levels can also be obtained using in situ gamma-ray spectrometry. Estimates of individual radionuclide contributions in soil can be made from field spectra, such as those developed by Beck and dePlanque (1966), Beck et al. (1972), and Anspaugh et al. (1974) as reported by Friesen (1982). Soil concentration estimates depend on the distribution of radioactivity with depth, soil density, soil moisture, and chemical composition.

A.2.5 Water

The basis for performing environmental water sampling and the requirements associated with surface-water sampling methods, locations, and frequencies are presented in the following subsections. Ground-water and vadose zone monitoring procedures are provided in Appendix C, along with additional discussions of surface-water sampling.

A.2.5.1 Basis for Sampling

The preliminary pathway analyses should provide the basis (establish the need) for water sampling. If there is the potential for site liquid effluents or surface runoff to be released to streams, rivers, or lakes, samples of these surface waters should be made according to the methods, locations, and frequencies specified in the subsections below.

The principal exposure pathways to individuals and/or groups of individuals in the environment from waterborne radionuclides at LLWDFs are ingestion of drinking water and consumption of irrigated crops. Of lesser importance is consumption of fish, ducks or other aquatic species, primarily because LLWDFs are sited away from major bodies of surface water.

Ground water may accumulate detectable radioactivity (particularly tritium) from seepage from waste disposal units/trenches or from accidental discharges to surface water. Further discussions of ground-water sources can be found in Appendix C.

Routine laboratory analyses on water samples should include those radionuclides, determined by pathway analyses, that represent a significant fraction of the potential dose from the water pathway (e.g, radiostrontium, gamma spectrometry) according to the radionuclides that could be released from the site and other potential sources.

Where documented operating experience and/or system design shows that no release (or significant potential for a release) will be made to surface waters, this portion of the environmental monitoring program may be reduced accordingly.

A.2.5.2 Locations

The basic recommendations that follow should be applied at all sites where there is the potential for discharge of radioactive liquid effluents or runoff to surface streams accessible to the public. Special studies, examining site-specific hydrological and surface flow, may be necessary to establish preferential sampling locations for ponds or lakes. Therefore, detailed hydrologic and radiologic studies should be conducted for each site on streams, ponds, and lakes to establish the best sampling locations and frequencies to evaluate potential environmental impact.

Surface waters can be divided into two basic types: those that are constantly moving (e.g., rivers and streams) and those that are not constantly moving (e.g., ponds and lakes). The type of surface water must be considered when specifying surface-water sampling location requirements.

Rivers and Streams. Representative surface-water background samples should be collected routinely at locations expected to be unaffected by site operations (i.e., upstream locations). Such "background" samples provide control data for comparison with data from downstream (potentially affected) indicator stations. Care should be taken to avoid any eddy currents. The other offsite sampling locations for surface water should be at the nearest down-current river or stream that could be affected by potential site effluents or runoff and the nearest point of withdrawal for domestic use. Multiple sampling points, based on diffusion and transport studies of the mixing zone, may be necessary to obtain a reliable estimate for those locations. Sampling at the first downstream point of withdrawal for public use provides an upper estimate of the amount of radioactivity in the water supply (for drinking or irrigation) of the potentially affected population group(s).

Ponds and Lakes. Representative background samples should be collected routinely for these surface-water sources at locations expected to be unaffected by site operations. Such locations should be far enough from the site so that any facility runoff has no (or as little as possible) influence on the sample content. If only a single body of water is available within the site area (i.e., within 10-15 km), then the "background" sample should be taken at a location that is at least 20% of the longer of the width or length of the pond or lake, and the indicator (downstream) sample taken at the nearest point of possible site runoff into that body of water.

Ground Water. Ground waters that may potentially be affected by site operations should be monitored (with adequate documentation) to determine the effects of such operations on ground-water quality and quantity and to demonstrate compliance with applicable federal and state laws and regulations. A ground-water monitoring plan should be developed as a specific element of all environmental monitoring plans. The ground-water monitoring plan will identify regulations applicable to ground-water protection and a monitoring strategy. The elements of the ground-water monitoring plan should be specified (including sampling plan, sampling, analysis, and data management), and the rationale or purpose for selecting these elements documented. The ground-water monitoring programs should be conducted onsite and in the vicinity of facility to:

1. obtain data for the purpose of determining baseline conditions of ground-water quality and quantity

2. demonstrate compliance with and implementation of all applicable regulations

3. provide data for the early detection of ground-water pollution or contamination

4. identify existing and potential ground-water contamination sources and to maintain monitoring of these sources

5. provide data upon which decisions can be made concerning land disposal practices and the management of ground-water resources.

The siting and number of ground-water monitoring stations should be governed by the nature of ground-water use and the location of known and potential sources of pollution. When possible, existing wells should be used. However, it is likely that new wells will be needed. Well siting should be directly related to pollutant pathways, but well locations must be chosen carefully to ensure that a new well does not itself provide an avenue for pollutants to reach the aquifer. Quality control in well construction is essential.

Predicting contaminant pathways requires a three-dimensional geologic, hydrodynamic, and geochemical analysis. Mechanisms for subsurface pollutant dispersal are not fully understood. The rate and extent of contamination are controlled by 1) the characteristics of the pollutant source, 2) the nature of the geologic formations in the saturated and unsaturated zones, and 3) the physical and chemical properties of the contaminants. Phenomena that affect the fate of a pollutant include capillary action, decay, adsorption, dispersion, and diffusion.

A.2.5.3 Frequency

All drinking water systems affected or potentially affected by the site should be monitored in accordance with the monitoring frequency requirements of 40 CFR 141.26. The sampling frequency and volume should be chosen to ensure adequate sensitivity for the analysis based on the exposure criteria given in 10 CFR 61.41.

A.2.5.4 Methods

Because most water measurements are made on samples taken in the environment and returned to the laboratory for analysis, the two major concerns in water sampling are the collection of a representative sample and the maintenance of radionuclides in their original concentrations prior to analysis. The general problem of the measurement of radioactivity in environmental water is discussed by Kahn (1972); water sampling procedures are also discussed in APHA (1971), EPA (1974), and ASTM (1986b) manuals.

Water Sample Collection. The following factors should be considered when selecting water sampling equipment:

- probability for significant fluctuations in concentration of the water sampled

- potential for significant human impact (dose)

- applicability to radionuclide(s) of interest.

The recommended practice for surface- and drinking-water samples is automated continuous sampling followed by analysis of the unfiltered sample. When the data are to be used for dose calculations, the method should use a fixed-time sampling frequency[(a)], similar to that by which water is withdrawn for human consumption. When circumstances prohibit this type of automated continuous sampling (e.g., power restrictions, prohibitive pumping requirements, freezing temperatures, etc.), compositing should be performed by manual collection on a frequency based on the potential for effluent release or surface runoff into the receiving body of water. An acceptable scheme is weekly to monthly grab samples composited for monthly to quarterly analyses.

Because the flow of most ground-water systems is on the order of centimeters to meters per day (compared with tens or even hundreds of kilometers per day for surface stream flows), periodic grab sampling of ground water should be sufficient. Unless circumstances prohibit, ground-water grab sampling should be done by pumping, either with a pressure air lift or with a submersible pump. In either case, the pump should be operated for a length of time sufficient to obtain a representative sample of water in the aquifer.

Sample Size. The size of water samples will be determined by the analytical procedures to be used. A 3.5- to 4.0-L (approximately 1-gal) sample is usually minimal for other than tritium or gross activity measurements. The sample volume must be increased where splitting of samples for replicate analysis or individual radionuclide determinations is planned.

Representative Sampling. Natural waters are frequently two-phased systems (i.e., solid materials are suspended in or floating on the water). Therefore, all surface-water samples should be carefully taken from beneath the water surface to avoid floating debris and any bottom sediments or growths.

Composite surface-water samples and all drinking-water samples should be analyzed without filtering, while all grab water samples should be filtered and the soluble and insoluble fractions each analyzed separately. The soluble fraction provides an indication of possible stream transport, while the insoluble fraction can be used as an indication of potential sedimentary material. To ensure comparability of data, both fractions should be added in reporting the total concentration.

(a) If the data therefrom are to be used for radionuclide transport or inventory purposes, these samples should be taken with timing proportional to flow rate.

Filtration of well (ground-water) samples is recommended since suspended material is usually an artifact of the sampling process (well-casing particles and dirt near water-soil interface) and is not representative of the ground water.

Caution should be exercised to ensure that water samples are not cross-contaminated by reuse of sampling containers. When obtaining surface-water grab samples, the sample container should be rinsed twice with the water being sampled before taking the actual sample. When extracting aliquots from a larger water sample, extra effort should be taken to ensure that the aliquot is representative of the entire sample.

Sample Preservation. Continuing biological and chemical action in the sample during and after collection cause changes in chemical form, deposition on container walls, and removal of radioactivity from solution by biological growths. Known phenomena include the following:

- Cations at very low concentrations can be lost from solutions; e.g., cesium can exchange with potassium in the container (glass).
- Radionuclides can be absorbed by algae or slime growths in sample containers, especially those that remain in the field for extended periods.
- Hydrolysis and sorption on container walls or on particles in the water can occur at low acidities (typical of many natural waters).
- Radiocolloidal phenomena may result in large flocculent particle formation or additional plate-out on container walls.
- Pretreatment may induce change in nuclide distribution; e.g., acidification can leach suspended particles in the original sample so that more radioactivity appears in solution.
- Acids used as biocides can oxidize iodide to iodine, resulting in its volatilization.
- Acids may quench standard liquid scintillation cocktails, invalidating tritium analysis.
- A change in counting geometry may occur for gamma-ray counting if finely divided particulate activity settles out or if soluble species become fixed on the container walls during counting.

Methods for Chemical Analysis of Water and Wastes (EPA 1974), Section 11 of the Annual Book of ASTM Standards (1986b), and the Environmental Measurement Laboratory (EML) Procedures (Harley 1986), should be used for sample preservation, storage, and analysis methods. The first two references list various preservative methods and permissible storage times for water samples according to chemical species, while the ASTM (1986b) and EML (Harley 1986) manuals provide methods for measurement of radioactivity and specific radionuclides. Because the additives used to preserve a sample for analysis on one radionuclide may adversely affect the ability to analyze the sample for a different radionuclide, the radioanalytical procedures to be used and the purpose of the measurement should govern which pretreatment, if any, is needed. For example, radioiodine analyses should not be performed on an acidified sample. Optimum preservation procedures should be determined by local testing, and then documented along with routine sampling procedures.

A.2.6 Aquatic Foodstuffs

The basis and procedural requirements for sampling of the various aquatic foodstuffs are presented in the following subsections.

A.2.6.1 Basis for Sampling

Aquatic foods, including local fish and waterfowl, may be eaten in relatively large quantities by residents of some regions of the country. Aquatic plants are not normally a component of the human diet in the United States. Preliminary pathway analysis should be performed and documented to determine which aquatic foods, if any, must be sampled to obtain data necessary for assessing radiation doses to the public.

If the preliminary analysis indicates that the annual effective dose equivalent from ingestion of aquatic foods is 5 mrem or greater, then sufficient sampling and analysis should be carried out to ensure that the foods and radionuclides contributing at least 90% of this ingestion dose are evaluated. If the annual effective dose equivalent is between 1 and 5 mrem, then sufficient sampling and analysis should be carried out to provide reasonable assurance that the doses are in this range. When the annual effective dose equivalent is projected to be less than 1 mrem, then sufficient monitoring should be done to show that the radionuclides are behaving in the environment as expected.

Because the concentration ratios for aquatic organisms (pCi/kg organism per pCi/L water) are greater than 1, any radionuclide present in the water will also be present in aquatic organisms, thereby providing a potentially greater deductibility in organisms than in water.

Aquatic organisms, sediments, and other predictive environmental media should be sampled and analyzed at least annually. The required sampling program is to be determined on a case-by-case basis considering factors such as the estimated dose, as determined from measured concentrations in organisms or predictive environmental media in comparison with the limits in 10 CFR 61.41, and any variation in behavior of the contaminants involved. The sampling program should be documented in the environmental monitoring plan.

A.2.6.2 Freshwater Foods

As a minimum, sampling and analysis should be performed annually for those foodstuffs shown by pathway analysis to represent significant potential exposures to the local populace. The sampling locations should include a "background" location unlikely to be affected by radionuclides released from the site and the place(s) of expected maximum radionuclide concentrations in the aquatic foods.

State and local game officials or aquatic biologists should be consulted when selecting the appropriate species to sample. Special permits from state fish and wildlife agencies are usually required for fish and waterfowl sampling for monitoring purposes.

Concentrations of many elements in freshwater are highly site dependent. This variation can affect the observed concentration ratios of radionuclides of these or biologically similar elements in fresh water organisms.

Fish. While it is not considered likely that any significant releases of radionuclides will occur to surface bodies of water in the vicinity of LLWDFs, probably the most important human exposures will come from consumption of fish. The species of fish likely to contain the highest concentrations of radionuclides are those that feed at or near the bottom and do not migrate very far from the places having the highest water or sediment concentrations. These species are useful as indicator organisms for monitoring trends in aquatic contamination levels. However, they may not always be the ones that are consumed at the highest rate by the local population. Studies of fishing pressure and fish consumption, coupled with preliminary radiochemical analysis of the different types of available fish, should be used to define the proper species to monitor for the purposes of dose calculation.

Fish can be collected by using nets or rod and reel. For use in dose calculations the edible portions of the fish as prepared for human consumption should be analyzed. In most instances, that includes only the muscle. However, the whole fish should be analyzed, if it is used for preparation of fish meal or fish burgers. It is also appropriate to analyze the whole fish when the data are used for trend indication; hence, for greater sensitivity the fish may be grouped by type (e.g., bottom feeders, insectivores, or predators) for analysis.

The following factors should be considered when determining the frequency of sampling: variability of the radionuclide release rates; seasonal variations in the feeding habits of the fish and in the availability to consumers; and the variability in the stream flow rate. Decisions on sampling locations and frequency should be documented.

Radionuclides of potential interest in fish include ^{65}Zn, ^{90}Sr, ^{134}Cs and ^{137}Cs. Strontium-90 might be of importance in samples of whole fish, because it concentrates mostly in bones. Phosphorous (^{32}P and ^{33}P) concentrates in fish flesh, as well as in bones. The sample size required for analysis will vary from 1 to several kg depending on the specific radionuclides being measured and their concentrations.

Waterfowl. Waterfowl, such as ducks and geese, may acquire radionuclides from their food sources. Some species are bottom feeders, and as such tend to accumulate those radionuclides associated with sediments, such as ^{60}Co, ^{65}Zn and ^{137}Cs. Others feed predominantly on surface plants, insects, or fish. Depending on the specific diet, these species may also accumulate ^{90}Sr in addition to the other activation and fission products noted previously.

The migratory habits of waterfowl species vary widely. Some may be year-round residents of the local waterways (and effluent ponds). These are usually species that are less desirable to hunters. Others may migrate long distances, and the limited amount of time spent in the local area may not be enough to cause significant contamination of their flesh. Because of these variables it is often difficult to predict which species is most important in terms of potential exposure to local hunters.

The preliminary pathway analysis should include consideration of the amount of waterfowl hunting, if any, in the local area and the number of birds shot. It should be remembered that, even though some individuals may harvest a relatively large number of waterfowl, the collective effective dose equivalent to the local population from waterfowl consumption may still be small. If hunting pressure is significant (as determined by state and local game officials), then a minimum of two or three birds (especially bottom feeders or plant eaters) should be sampled during hunting season. The most common method of collecting waterfowl is by hunting. Local game officials should be contacted to obtain sampling permits and advice on the proper species to collect. Sampling of nonmigratory, nongame species can occasionally provide useful information on contamination trends.

During preparation of the samples for analysis, care should be exercised not to contaminate the edible portions with radionuclides present on the external surfaces of waterfowl. Analysis should include the radionuclides listed above plus any others that prove to be of special concern at a specific site.

A.2.7 Sediment

The basis for performing environmental sediment sampling and the requirements associated with sediment sampling methods, locations, and frequencies are presented in the following subsections.

A.2.7.1 Basis for Sampling

The sampling of sedimentary material from streams, ponds, or even playas can provide an indication of the accumulation of undissolved radionuclides in the aquatic environment. The accumulation of radioactive materials in sediment can lead to exposure to humans through aquatic species, through resuspension into drinking water supplies, or as an external radiation source to people fishing, wading, or sunbathing. Hence, the sampling and analysis of sediment, or the measurement of the external radiation emanating therefrom, provide indications of the potential for human exposure from these indirect pathways. Because of the accumulation of contaminants, sediment sampling is a more sensitive indicator of waterborne radionuclides than water sampling or, for some aquatic species, aquatic biota sampling. This is especially true for radionuclides that are not significantly accumulated by fish or shellfish. Sediment sampling is particularly appropriate for most of the transuranics (especially ^{239}Pu); such activation products as ^{54}Mn, ^{58}Co, ^{60}Co, and ^{65}Zn; and several fission products such as ^{95}Zr-Nb, ^{134}Cs, and ^{137}Cs.

A.2.7.2 Location and Frequency

The need for sediment sampling and the choice of locations and frequency should be based on site-specific evaluations. These evaluations should consider the potential for offsite exposure of humans, as well as the potential dose to onsite or offsite aquatic organisms. Sediment samples are normally taken to detect the buildup of radionuclides by sedimentation. Sediment sampling locations should be based on the type of surface water receiving site liquid effluents. For moving bodies of water, such as streams or rivers, sediment sampling locations should include an upstream site beyond any possible facility influence and two downstream locations. The two downstream locations should be located such that one is near the discharge site and the other is in an area that favors sedimentation - such as the inner bank of a bend (EPA 1972) in the stream or river, or at a dam impoundment. If liquid effluents or surface runoff from a LLWDF are discharged to a lake, pond, or arroyo, a sediment sample should be taken near the outfall but beyond the turbulent area created by the effluents (runoff).

Because sediments are usually not in a critical exposure pathway, an annual frequency for sediment sampling should be sufficient. For rapidly moving streams (e.g., rivers), sediment sampling should be considered in conjunction with the spring freshet (i.e., just before or just after), if one occurs locally. For playas and arroyos, the sampling should take place after cessation of water flow (i.e., upon first drying in the spring). For ponds or lakes, the timing of sediment sampling should be considered on a site-specific basis, but normally at about the same time each year.

A.2.7.3 Sediment Sampling

Samples of deposited sediments in water can be collected manually (by hand in shallow water, or by diving in deeper water), or mechanically (by dredge or with a core sampler). The manual methods are recommended where conditions permit because location and depth of sample can be well-defined. The dredge and coring methods use a sampling device dropped from a boat that is activated when the device contacts the sediment (benthos).

Except for cases where an inventory estimation is desired, representative surface (top 5-10 cm) sediment samples should be collected along with water depth and stream flow (or pond/lake elevation) data at the time of sampling. Characteristics of the sample, such as particle size distribution, sediment type, stream type (i.e., intermittent, creek, pond, river, reservoir, etc.), ion-exchange capacity, and organic content, may be useful for proper interpretation of the analytical results.

All sediment samples should be oven-dried, homogenized (by grinding and blending, as appropriate in accordance with procedures used) and the radio-analytical results reported on the basis of activity per unit dry weight (g or kg). To prevent cross-contamination, thorough cleaning of equipment between samples is necessary. Portions of the detailed Environmental Measurement Laboratory (EML) procedures (Harley 1986) for preparing soil samples for analysis are equally applicable to sediment samples.

A.3 ENVIRONMENTAL MONITORING PROGRAMS

This section provides, in tabular format, a summary of the good monitoring practices discussed in Section A.2. A summary of suggested monitoring programs for each of the three phases--preoperational, operational, and postoperational--in the life cycle of an LLWDF is provided separately in this section. Because of the potential differences between arid and humid sites, suggested monitoring programs are shown separately for each in the operational section (A.3.2).

A.3.1 Preoperational Programs

Suggested sampling program components for preoperational radiological environmental monitoring programs at LLWDFs are provided in Table A.1 and in Figure A.2. A listing of suggested types and numbers of analyses is provided in Table A.2. These tables, with minor modifications, and Figure A.2 are taken directly from Section 4 of the LLW Handbook (Sedlet and Wynveen 1983). The information in these tables and the accompanying figure provides guidance for evaluating the adequacy of proposed preoperational environmental monitoring programs for radiological components.

The suggested analysis schedule provided in Table A.2 does not address all of the radionuclides or analyses that may be necessary, such as those for the transuranic elements.

A.3.2 Operational Programs

Suggested sampling program components for operational radiological environmental monitoring programs at LLWDFs are provided in Tables A.3 and A.4. Table A.3 is for an arid site and Table A.4 is for a humid site. These tables were taken from Section 4 of the LLW Handbook (Sedlet and Wynveen 1983).

A.3.3 Postoperational Programs

Because site-specific conditions at the time of or just before final site closure cannot be predicted with certainty, it is not practical to design a postoperational environmental monitoring program with the same degree of specificity, such as numbers of samples to be collected or the numbers of analyses to be performed, as were provided for the preoperational and operational periods.

Specific environmental monitoring concerns during the short-term care period (up to 5 years) following site closure should address those site activities that could disturb or alter the already disposed of waste. This could include the possibility of resuspending or bringing previously buried contamination to the surface during final earth-moving operations at the site. The most probable long-term (the 100-year institutional care period) pathway for radionuclide migration will be through ground-water transport. Hence, the emphasis during this period should be on the potential subsurface zones for water transport and eventual routes to man, either through ground water being used for drinking or irrigation purposes or the ground water reaching a surface stream or body of water some distance downgradient of the disposal site.

TABLE A.1. Suggested Media, Frequency and Number of Samples for Preoperational Environmental Monitoring Programs at LLWDFs (from Sedlet and Wynveen 1983)

Sample Type	Sampling Frequency	Arid[(a)] Number	Humid[(a)] Number
Air			
Particulate	Continuous, changed weekly	2 perimeter	2 perimeter
Tritiated water vapor	Continuous, changed weekly	2 perimeter	2 perimeter
Gases and radioiodine	Continuous, changed weekly	2 perimeter	2 perimeter
Precipitation	Monthly	1 perimeter location	1 perimeter location
TLD (or other)[(b)]	Continuous, exchanged bimonthly	6 perimeter	6 perimeter
Water			
Surface	Semiannually	Lakes, streams, ponds, rivers, within 10 km	
Ground--offsite	Semiannually	Municipal and private wells within 10 km	
Ground--onsite	Quarterly	8 perimeter monitoring wells in the saturated zone and any wells into aquifers	
Bottom sediment	Annually	Nearby rivers that drain area, if within 10 km	Nearby rivers that drain the site (upstream and downstream)
Soil			
Subsurface	Once	Collect soil at time boreholes are dug	
Surface--onsite	Annually	Divide soil in grid system of 100 x 100-meter squares and take one soil sample from each grid	
Surface--offsite	Semiannually	Collect 17 samples using the sampling scheme provided in Figure A.2	
Vegetation			
Grass	Annually with soil	None[(c)]	Collect grass samples at 30% of the soil sampling locations
Other--onsite and nearby	Once	Representative samples of the common vegetation[(d)] of the area	
Wildlife			
Small mammals	Once	Representative samples of the common species of the area	
Game birds	Once	In-season species at convenient locations within 10 km of the site	
Fish	Once	Nearest river that drains area	Upstream from site and downstream where seepage or runoff from the site may occur

Table A.1. (Contd)

Sample Type	Sampling Frequency	Arid[a] Sampling Number	Humid[a] Sampling Number
Farm Produce			
Vegetation	Once	Representative samples of the major constituents within 10 km of site	
Milk	Semiannually when cows are in pasture, and from a local dairy	If available	Upwind and downwind of the site

(a) For the purpose of this document, sites where the unsaturated zone extends for greater than about 50 ft below the bottom of the disposal units are defined as arid; those sites where the unsaturated zone is less than about 50 ft are classed as humid. However, it should be noted that arid and humid are extremes of a continuum of conditions.
(b) For direct radiation measurements.
(c) Grasses are normally not available in an arid area.
(d) While many native vegetation types may be available in a humid area, desert samples are more likely to be confined to thistles, shrubs, and sagebrush.

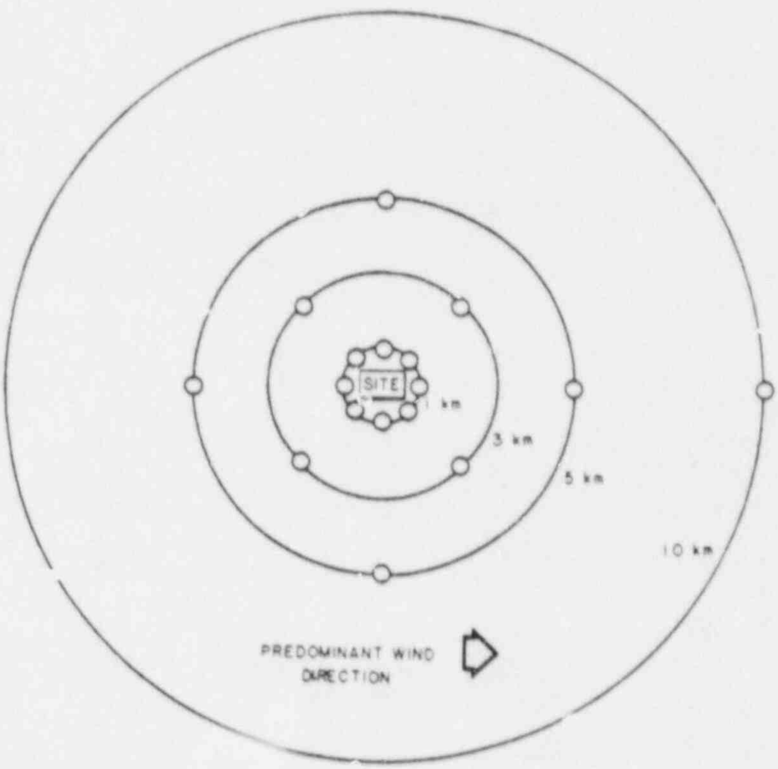

FIGURE A.2. Surface Soil-Sampling Pattern (from Harley 1986)

TABLE A.2. Suggested Radioanalyses[(a)] for Preoperational Environmental Monitoring Programs at LLWDFs (from Sedlet and Wynveen 1983)

Sample Type	Analysis: Total Alpha	Total Beta	Gamma Scan[(b)]	^{3}H	^{14}C	^{85}Kr	^{90}Sr	^{99}Tc	^{129}I	^{222}Rn	^{226}Ra	U
Air[(c)]												
Particulate	100	100	MC[(d)]									
Water vapor				100								
Other vapors, gases					100	100			100	50		
Precipitation			100									
Water			50	100	10		25	10			10	
Bottom sediment			100									
Soil												
Offsite			100	100[(e)]			100					100
Onsite[(f)]			100	100			100					100
Subsurface			10	10			10					10
Vegetation												
Grass			30	30								
Other[(g)]			100	100								
Wildlife[(g)]			100									
Farm Produce												
Vegetation			100									
Milk			100	100			100		100			

(a) Values shown are the percentage of samples collected to be evaluated by the respective techniques or for the respective radionuclides.
(b) Analysis by gamma spectrometry to identify gamma-emitting radionuclides in the sample matrix (typical radionuclides include ^{60}Co and ^{137}Cs).
(c) Includes direct radiation, evaluated by bimonthly exchange and readout of thermoluminescent dosimeters (TLDs).
(d) Each monthly composite by location.
(e) Soil moisture.
(f) Analyze only 30 of total number collected; balance of samples expected to be archived for subsequent analysis as required.
(g) By species.

TABLE A.3. Suggested Media, Frequency, Location and Number of Samples for Operational Environmental Monitoring Programs for LLWDFs - Arid Site (from Sedlet and Wynveen 1983)

Sample Type	Frequency	Number and Location
Air		
Particulate	Continuous--changed weekly	6 perimeter--4 offsite
Tritiated water vapor	Continuous--changed weekly	4 perimeter--2 offsite
Gases and iodine	Continuous--changed weekly	2 perimeter--2 offsite
Precipitation	Monthly	1 perimeter location
TLD (or other)[a]	Bimonthly	6 perimeter--4 offsite
Water		
Surface	Semiannually	Water that drains the site and at that location that is downstream of the site and drains the area
Ground--onsite	Monthly	Trench sumps and trench monitoring line wells, from modeling results
Ground--onsite	Quarterly	12 perimeter monitoring wells and any wells into aquifers
Ground--offsite	Semiannually	Up to 10 locations within 10 km
Bottom sediment	Annually	Above and below the site
Soil		
Surface	Annually	10 onsite--10 offsite
Subsurface--onsite	Once	Representative samples of the dominant species of the area
Farm Produce		
Vegetation	Annually	Representative samples of the common species that inhabit the site
Milk	Quarterly	Upwind and downwind of the site
Wildlife		
Small mammals--onsite	Annually	Representative samples of the common species that inhabit the site
Game birds	Annually	In-season species at convenient locations within 10 km of the site
Fish	Annually	Upstream and downstream of the site

(a) For direct radiation measurements.

TABLE A.4. Suggested Media, Frequency, Location and Number of Samples for Operational Environmental Monitoring Programs for LLWDFs - Humid Site (from Sedlet and Wynveen 1983)

Type	Frequency	Number and Location
Air		
Particulate	Continuous--changed weekly	6 perimeter--4 offsite
Tritiated water vapor	Continuous--changed weekly	4 perimeter--2 offsite
Gases and iodine	Continuous--changed weekly	2 perimeter--2 offsite
Precipitation	Monthly	1 perimeter location
TLD (or other)[(a)]	Bimonthly	6 perimeter--4 offsite
Water		
Surface--onsite	Continous collection or weekly grab	Water that drains the site and at that location that is downstream of the site and drains the area
Ground--onsite	Monthly	Trench sumps and trench monitoring line wells, from modeling results
Ground--onsite	Monthly	12 perimeter monitoring wells and any wells into aquifers
Ground--offsite	Quarterly	Up to 10 locations within 10 km
Bottom sediment	Annually	Above and below the site
Soil		
Surface	Annually	10 onsite--10 offsite
Subsurface	Once	Collect a representative number of cores from each borehole as dug
Farm Produce		
Vegetation	Annually	Representative samples of the common species that inhabit the site
Milk	Quarterly	Upwind and downwind of the site
Wildlife		
Small mammals--onsite	Annually	Representative samples of the common species that inhabit the site
Game birds	Annually	In-season species at convenient locations within 10 km of the site
Fish	Annually	Upstream and downstream of the site

(a) For direct radiation measurements.

A.4 REFERENCES

American Conference of Governmental Industrial Hygienists. 1974. Air Sampling Instruments for Evaluation of Atmospheric Contaminants, 4th Edition. American Conference of Governmental Industrial Hygienists, Washington, D.C.

American National Standards Institute (ANSI). 1969. Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities. ANSI N13.1-1969, American National Standards Institute, Inc., New York, New York.

American National Standard Institute (ANSI). 1975. American National Standard - Performance, Testing, and Procedural Specifications for Thermoluminescent Dosimetry: Environmental Applications. ANSI N545-1975, American National Standards Institute, Inc., New York, New York.

American Public Health Association (APHA). 1971. Standard Methods for the Examination of Water and Wastewater, 13th Edition. American Public Health Association, Washington, D.C.

American Public Health Association (APHA). 1972. Methods of Air Sampling and Analysis. American Public Health Association, Intersociety Committee for a Manual of Methods for Ambient Air Sampling and Analysis, Washington, D.C.

American Society for Testing and Materials (ASTM). 1986a. Nuclear, Solar, and Geothermal Energy, Vol. 12.02. American Society for Testing and Materials, Philadelphia, Pennsylvania.

American Society for Testing and Materials (ASTM). 1986b. Water and Environmental Technology, Vol. 11.02. American Society for Testing and Materials, Philadelphia, Pennsylvania.

Anspaugh, L. R., P. L. Phelps, P. H. Gudiksen, C. L. Lindeken, and G. W. Huckabay. 1974. "The In-Situ Measurement of Radionuclides in the Environment with a Ge(Li) Spectrometer." In Proceedings of the Second International Symposium on the Natural Radiation Environment, J. A. S. Adams, W. M. Lowder, and T. Gesell, eds. Atomic Energy Commission, Washington, D.C.

Beck, H. L., and G. dePlanque. 1966. The Radiation Field in Air Due to Distributed Gamma-Ray Sources in the Ground. HASL-195, Health and Safety Laboratory, New York, New York.

Beck, H. L., J. DeCampo, and C. Gogolak. 1972. In Situ Ge(Li) and NaI(Tl) Gamma-Ray Spectrometry. HASL-256, Health and Safety Laboratory, New York, New York.

Bellamy, R. R. 1974. "Elemental Iodine and Methyl Iodide Adsorption on Activated Charcoal at Low Concentrations." In Nuclear Safety, Vol. 1516, pp. 711-723. U.S. Atomic Energy Commission Technical Information Center, Oak Ridge, Tennessee.

Brown, R., H. E. Meyer, B. Robinson, and W. E. Sheehan. 1973. A Ruggedized Ultrasensitive Field Air Sampler for HTO and HT. MLM-2015, Mound Laboratory, Monsanto Research Corp., Miamisburg, Ohio.

Corley, J. P., D. H. Denham, R. E. Jaquish, D. E. Michels, A. R. Olsen, and D. A. Waite. 1981. A Guide For: Environmental Radiological Surveillance at U.S. Department of Energy Installations. DOE/EP-0023, U.S. Department of Energy, Washington, D.C.

Denham, D. H. 1979. "Environmental Radiological Monitoring in Perspective: The Relative Importance of Environmental Media as a Function of Effluent Pathway and Radionuclides." Health Phys. 36:273-281.

dePlanque, G. 1972. Investigation of a CaF_2:Mn Thermoluminescent Dosimetry System for Environmental Monitoring. HASL-252, U.S. Atomic Energy Commission Health and Safety Laboratory, New York, New York.

dePlanque, G., and T. F. Gesell. 1982. "Thermoluminescence Dosimetry - Environmental Applications." International Journal Applied Radiation and Isotopes 33:1015-1034.

dePlanque, G., T. F. Gesell, and K. Becker. 1976. "Second International Intercomparison of Environmental Dosimeters Under Field and Laboratory Conditions." In Proceedings of the Tenth Midyear Topical Symposium of the Health Physics Society, pp. 555-574. Rensselaer Polytechnic Institute, Troy, New York.

Fix, J. J., and M. L. Miller. 1978. The Hanford CaF_2:Mn Thermoluminescent Dosimeter. PNL-2489, Pacific Northwest Laboratory, Richland, Washington.

Fleischhauer, H. L. 1984. Procedures for Sampling Radium-Contaminated Soils. GJ/TMC-13, U.S. Department of Energy, Grand Junction, Colorado.

Fowler, E. B., W. Henderson, and F. Milligan, compilers. 1971. Proceedings of Environmental Plutonium Symposium--August 4-5, 1971. LA-4756, University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

Friesen, B. 1982. Radiological Support Project Final Report. NVO-213, U.S. Department of Energy, Las Vegas, Nevada.

Gabay, J. J., C. J. Paperiello, S. Goodyear, J. C. Daly, and J. M. Matuszek. 1974. "A Method for Determining Iodine-129 in Milk and Water." Health Phys. 26:89-96.

Gesell, T. F. 1982. Environmental Monitoring with Thermoluminescence Dosimetry, IEEE Transactions on Nuclear Sci. NS-29(3):1225-1232.

Gesell, T. F., F. L. Kalbeitzer, and G. dePlanque. 1982. "Highlights of the Sixth International Intercomparison of Environmental Dosimeters." Radiation Protection Dosimetry 6(1-4):265-268.

Grossman, R. F., and R. W. Holloway. 1985. "Concentrations of Krypton-85 Near the Nevada Test Site." Environmental Science and Technology 19:1128-1131.

Hall, R. M., and J. P. LaRocca. 1966. "Thermoluminescent Dosimeters for Environmental Monitors." Health Phys. 12:851-852.

Harley, J. H. 1986. HASL Procedures Manual (revised annually). HASL-300, U.S. Department of Energy, New York, New York.

Healy, J. W. 1984. A Proposed Interim Standard for Plutonium in Soils. LA-5483-MS, University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

Hendee, W. R. 1967. "Radiation Response of LiF at Low Doses." Health Phys. 13:1235-1236.

Hoy, J. E. 1971. "Environmental Radiation Monitoring with Thermoluminescent Dosimeters." Health Phys. 21:860-862.

International Commission on Radiological Protection (ICRP). 1985. Principles of Monitoring for the Radiation Protection of the Population. ICRP Publication 43, Pergamon Press, New York, New York.

International Organization for Standardization (ISO). 1975. General Principles for Sampling Airborne Radioactive Materials. ISO 2889-1975 (E), International Organization for Standardization, Geneva, Switzerland.

Jackson, W. M., J. D. Spaulding, J. E. Noakes, and G. L. Murphy. 1985. "Comparison of Environmental Radiation Dosimetry and γ-ray Spectroscopy." Health Phys. 48:747-756.

Kahn, B. 1972. "Determination of Radioactive Nuclides in Water." In Water and Waste Pollution Handbook, L. L. Ciacco, ed. Marcel Dekker, New York, New York.

Keller, J. H., T. R. Thomas, D. T. Spence, and W. J. Maeck. 1973. "An Evaluation of Materials and Techniques Used for Monitoring Airborne Radioiodine Species." In Proceedings of the Twelfth AEC Air Cleaning Conference. U.S. Atomic Energy Commission, Washington, D.C.

Ludwig, F. L. 1976. "Siting Air Monitoring Stations." Environmental Science and Technology 12:7.

Mejdahl, V. 1970. "Measurement of Environmental Radiation Intensity with Thermoluminescent $CaSO_4$:Dy." Health Phys. 18:164-167.

Meyer, H. R., and J. Purvis. 1985. "Development of an Interference - Corrected Soil Radium Measurement System." In Transactions American Nuclear Society, Vol. 50, pp. 184-187. American Nuclear Society, LaGrange Park, Illinois.

Mohrand, R. A., and L. A. Franks. 1982. Compilation of ^{137}Cs Concentrations at Selected Sites in the Continental United States. EGG-1183-2437-Rev, EG&G, Inc., Goleta, California.

Myrick, T. E., B. A. Berven, and F. F. Haywood. 1983. "Determination of Selected Radionuclides in Surface Soil in the United States." Health Phys. 45:631-642.

National Council on Radiation Protection and Measurements (NCRP). 1985. A Handbook of Radioactivity Measurements Procedures, 2nd Edition. NCRP Report No. 58, National Council on Radiation Protection and Measurements, Bethesda, Maryland.

National Low-Level Waste Management Program, Environmental Monitoring for Low-Level Waste Disposal Sites. DOE/LLW-13TG-1983, U.S. Department of Energy, Washington, D.C.

Osborne, R. V. 1974. "Sampling for Tritiated Water Vapour." In Proceedings of the Third International Congress of the International Radiation Protection Association, September 9-14, 1973, Washington, D.C. Paper No. 222, U.S. Atomic Energy Commission Technical Information Center, Oak Ridge, Tennessee.

Regulatory Guide 1.21, Rev. 1 (1974); "Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants." U.S. Nuclear Regulatory Commission (NRC), Washington, D.C.

Regulatory Guide 1.52 (1976); "Design, Testing, and Maintenance Criteria for Post-Accident Engineered-Safety-Feature Atmosphere Cleanup System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants." U.S. Nuclear Regulatory Commission (NRC), Washington, D.C.

Regulatory Guide 4.1 (1975); "Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants." U.S. Nuclear Regulatory Commission, Office of Standards Development, Washington, D.C.

Regulatory Guide 4.5 (1974); "Measurement of Radionuclides in the Environment - Sampling and Analysis of Plutonium in Soil." U.S. Nuclear Regulatory Commission, Atomic Energy Commission Directorate of Regulation, Washington, D.C.

Regulatory 4.6 (1974); Measurements of Radionuclides in the Environment, Strontium-89 and Strontium-90 Analyses." U.S. Atomic Energy Commission, Washington, D.C.

Regulatory Guide 4.13, Rev. 1 (1977); "Performance, Testing, and Procedural Specifications for Thermoluminescent Dosimetry: Environmental Applications." U.S. Nuclear Regulatory Commission, Office of Standards Development (NRC). 1977. U.S. Nuclear Regulatory Commission (NRC), Washington, D.C.

Regulatory Guide 6.25 (1980); "Calibration and Error Limits of Air Sampling for Total Volume of Air Sampled." U.S. Nuclear Regulatory Commission (NRC), Office of Standards Development, Washington, D.C.

Regulatory Guide 8.6 (1973); "Standard Test Procedure for Geiger-Müller Counters." U.S. Atomic Energy Commission, Washington, D.C.

Regulatory Guide 8.25 (1980); "Calibration and Error Limits of Air Sampling Instruments for Total Volume of Air Sampled." U.S. Nuclear Regulatory Commission, Office of Standards and Development, Washington, D.C.

Sedlet, J., and R. A. Wynveen. 1983. Low-Level Radioactive Waste Management Handbook Series - Environmental Monitoring for Low-Level Waste-Disposal Sites. DOE/LLW-13Tg, U.S. Department of Energy, Idaho Falls, Idaho.

Sill, C. W., and R. L. Williams. 1971. "Rapid Identification and Determination of Alpha Emitters in Environmental Samples." In Rapid Methods for Measuring Radioactivity in the Environment, p. 201. International Atomic Energy Agency, Vienna, Austria.

Stanley, R. E., and A. R. Moghissi, eds. 1975. Noble Gases. CONF-730915, U.S. Energy Research and Development Administration, Washington, D.C.

Toxic Substances Control Act, as amended, U.S. Code, Title 15, Sec. 2601 et seq. (1976).

Trevathan, M. S., and K. R. Price. 1985. "Ambient Krypton-85 Air Sampling at Hanford." in Proceedings of the Fifth DOE Environmental Protection Information Meeting. U.S. Department of Energy, Washington, D.C.

Urabe, I., and K. Katsurayama. 1984. "Feasibility Study on a Continuous Environmental Gamma-Ray Monitor Using a NaI(Tl) Scintillation Spectrometer." Health Phys. 47:559-566.

U.S. Environmental Protection Agency (EPA). 1972. Environmental Radioactivity Surveillance Guide. ORP/SID 72-2, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1974. Methods for Chemical Analysis of Water and Wastes (with latest revisions). EPA 625/6-74-003, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Geological Survey (USGS). 1977. National Handbook of Recommended Methods for Water-Data Acquisition. U.S. Department of the Interior, Reston, Virginia.

U.S. Code of Federal Regulations, Title 10, Part 61 (10 CFR 61); "Licensing Requirements for Land Disposal of Radioactive Waste."

U.S. Code of Federal Regulations, Title 40, Part 61 (40 CFR 61); "Regulations on National Emission Standards for Hazardous Air Pollutants."

U.S. Code of Federal Regulations, Title 40, Part 141 (40 CFR 141); "National Primary Drinking Water Regulations."

U.S. Nuclear Regulatory Commission (NRC). 1985. Suggested State Requirements and Criteria for a Low-Level Radioactive Waste Disposal Facility. NUREG/CR-4352, U.S. Nuclear Regulatory Commission, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988 (Draft). "Technical Position Paper - Environmental Monitoring of Low-Level Waste Disposal Facilities." U.S. Nuclear Regulatory Commission, Washington, D.C.

Waite, D. A. 1973a. Analysis of an Analytical Technique for Distributing Air Sampling Locations Around Nuclear Facilities. BNWL-SA-4676, Pacific Northwest Laboratory, Richland, Washington.

Waite, D. A. 1973b. An Analytical Technique for Distributing Air Sampling Locations Around Nuclear Facilities. BNWL-SA-4534, Pacific Northwest Laboratory, Richland, Washington.

Watson, J. E. (Chairman). 1980. Upgrading Environmental Radiation Data, Health Physics Society Committee Report HPSR-1 (1980). EPA 5201/1-80-01, U.S. Environmental Protection Agency, Washington, D.C.

APPENDIX B

METEOROLOGICAL MONITORING PROGRAMS

APPENDIX B

METEOROLOGICAL MONITORING PROGRAMS

Environmental protection activities, including the assessment of impacts of airborne releases on public health and safety and the demonstration of compliance with applicable federal, state, and local laws, regulations, and Orders, require meteorological information representative of conditions at low-level radioactive waste disposal facilities. This information is needed to assess the transport, diffusion, and deposition of materials released to the atmosphere by the facilities. It is also important in the design of environmental monitoring networks.

Each low-level radioactive waste disposal site should establish a meteorological monitoring program that is appropriate to the activities at the site, the topographical characteristics of the site, and the distance to critical receptors. The scope of the program should be based on an evaluation of the meteorological data needed for impact assessments, environmental surveillance activities, and emergency response.

The basis for development of the meteorological monitoring program should be the selection of an appropriate set of computational techniques for a range of environmental applications. For each site, the factors considered should include: the magnitude of potential source terms, possible pathways to the atmosphere, distances from release points to critical receptors, and proximity of the site to other facilities having releases of radioactivity. The type of meteorological information required for a low-level waste facility is not explicit in laws and orders, but it is implicit in regulations and directives. In general, low-level waste disposal sites should take onsite measurements of wind direction, wind speed, and atmospheric stability to evaluate atmospheric dispersion in the vicinity of facilities and to perform the required dose calculations. Larger low-level waste disposal sites may need monitoring programs that include additional meteorological measurements and measurements at more than one location to adequately evaluate transport and diffusion of effluents. This section provides guidance in selection and operation of meteorological instrumentation to obtain the required information.

Some sites may be able to establish a meteorological program that makes use of meteorological measurements obtained from offsite sources such as the National Weather Service. For data from an offsite source to be acceptable, the data must be representative of conditions at the low-level waste disposal facility; the instrumentation must be well-maintained; and statistically valid, hourly data must be readily available.

Specific meteorological information requirements for each facility should be based on the magnitude and nature of potential releases from the facility and the mathematical procedures and models used in dose assessment. Dose assessment includes estimation of the transport, diffusion, and deposition of material released to the atmosphere. Methods that are appropriate for estimating transport and diffusion at a facility depend on the type, size, and location of the facility.

Meteorological information requirements for facilities should also be based on environmental monitoring and surveillance requirements. For example, meteorological information is required in the selection of locations for monitoring stations if monitoring is to take place at the projected point of maximum impact of a facility.

B.1 METEOROLOGICAL PROGRAM BASIS

The principal use of meteorological data at a low-level waste disposal site is for atmospheric dispersion calculations, which are required to:

1. assess the potential consequences of releases from projected new or modified facilities

2. assess the consequences of actual routine releases

3. demonstrate compliance with regulations and standards

4. assess the consequences of actual accidental releases.

Atmospheric dispersion calculations used for dose assessment vary in sophistication and complexity from relatively simple computations to extensive computations that require computers. Similarly, the meteorological data required for these calculations range from minimal for some of the simple techniques to extensive data sets for some of the computer-intensive techniques. The meteorological input to the AIRDOS-EPA model (Moore et al. 1979) includes the joint frequency distribution of wind dir tion and atmospheric stability, and an average wind speed for each combinat on of wind direction and stability. The model also requires an average mixing layer depth and an average temperature.

Meteorological monitoring programs for low-level waste disposal sites should provide the data for use in atmospheric transport and diffusion computations that are appropriate for the site and application. Before any model is deemed appropriate for a specific application, the assumptions upon which the model is based should be evaluated and the evaluation results documented. For example, assumptions that are reasonable in models used to demonstrate compliance with annual average concentration standards are not reasonable in models used for emergency response applications.

Meteorological programs for sites where onsite meteorological measurements are not necessary should include a description of climatology in the vicinity of the site and should provide ready access to representative meteorological data. Data from offsite sources, such as the National Weather Service, the Federal Aviation Administration, or military installations, may be used as long as the meteorological instruments are well-maintained and the data are readily available and representative of conditions at the site.

As the maximum magnitude of potential releases from a facility increases, it becomes necessary to use more realistic models to assess the consequences of the releases or demonstrate compliance with laws and regulations. Potential release modes, distances from release points to receptors, and meteorological conditions should be considered in assessments for low-level waste disposal facilities requiring onsite measurements. Computational techniques based on straight-line Gaussian models, for example, AIRDOS-EPA (Moore et al. 1979), are appropriate for facilities that are located in simple topographic settings. Straight-line Gaussian models are described in detail in many documents including Meteorology and Atomic Energy - 1968 (Slade 1968; Gifford 1968) and Atmospheric Science and Power Production (Randerson 1984a,b; Barr and Clements 1984). As a minimum, these models require specification of wind direction, wind speed, and atmospheric stability. They may require the specification of a mixing-layer thickness. If the models estimate deposition, they may require information on precipitation, and if the models compute plume rise for stack releases, the ambient air temperature may be required.

Straight-line Gaussian models are not appropriate for facilities that are located in valleys, near coasts or mountains, and on large sites. In these settings, strictly applied straight-line Gaussian models may underestimate the consequences of a release, as well as incorrectly identify locations where significant consequences occur. Trajectory models provide more realistic assessments in these settings.

Trajectory models (Powell et al. 1979; Ramsdell et al. 1983; Petersen et al. 1984; Scherpelz et al. 1986) treat atmospheric transport and diffusion as separate processes. This additional complexity is necessary in order to treat spatial and temporal variations of the atmosphere. These models generally require the same types of meteorological data as the straight-line models. However, to make full use of their capabilities to characterize spatial variations, it is necessary to use meteorological data from more than one location. In addition, input to trajectory models is generally a series of hourly meteorological observations that include wind direction and speed, stability, temperature, and mixing-layer depth, rather than sets of frequency distributions.

B.2 DIFFUSION COEFFICIENTS

Gaussian straight-line and trajectory models make use of diffusion coefficients (commonly referred to as sigma y and sigma z) to describe the spread of plumes. These coefficients are generally estimated on the basis of an atmospheric stability class and the distance that the material has traveled since its release. The turbulence that causes diffusion is related to atmospheric stability; stability classes are used to permit climatological summarization of data. Gifford (1976) discusses various methods for determining diffusion coefficients.

Routine meteorological measurements by the National Weather Service and other organizations typically do not include the direct measurement of atmospheric stability or the determination of stability classes. Instead, a method of estimating stability classes based on wind speed and cloud cover (Pasquill

1961; Gifford 1961; Turner 1964, 1969) is used by the National Weather Service and the National Climatic Data Center to estimate stability classes from routine meteorological observations. The meteorological data required include cloud cover, ceiling height, and wind speed.

Common methods of determining stability classes from onsite meteorological measurements include use of vertical temperature gradient, standard deviation of the wind direction (sigma theta), and the standard deviation of the elevation angle of the wind (sigma phi). The methods using the temperature gradient and sigma theta are described in ANSI/ANS-2.5-1984 (ANSI 1984) and NRC Regulatory Guide 1.23. Irwin (1980) discusses the sigma theta and sigma phi methods and presents a method that uses both sigma theta and wind speed. This method is described in the EPA air quality modeling guidelines (EPA 1986). The temperature gradient method of determining stability class has been held by the ANS and the NRC to be acceptable for estimating both the horizontal and vertical diffusion coefficients, while the sigma theta method has been held to be acceptable only for estimating the horizontal diffusion coefficient.

Numerous studies (Luna and Church 1972; Skaggs and Robinson 1976; Horst et al. 1979; Lalas et al. 1979; Weil 1979; Lague et al. 1980; Sedefian and Bennett 1980; Mitchell 1982) have compared methods of determining stability classes. When hourly data are examined, the results of the various methods are not highly correlated. Consequently, the use of stability classes should be avoided when assessing the effects of short duration releases that take place at a known time. Diffusion coefficients for this application may be estimated directly from atmospheric turbulence measurements (Hanna et al. 1977; Pasquill 1979; Irwin 1983). Turbulence data for estimating the horizontal diffusion coefficient can be obtained from the same sensors used for wind direction and speed measurements with additional signal processing. Obtaining turbulence data for estimating vertical diffusion coefficients generally requires special but readily available sensors.

B.3 METEOROLOGICAL MEASUREMENTS

Meteorological measurements should be made in locations that provide data representative of the atmospheric conditions into which material will be released and transported. A meteorologist or other atmospheric scientist with experience in atmospheric dispersion and meteorological instrumentation should be consulted in selection of measurement locations and in the design and installation of the meteorological measurement system. Factors to be considered in selecting measurement locations and installation of the instruments include the prevailing wind direction, topography, and obstructions.

The instruments used in the monitoring program should be capable of continuous operation in the normal range of atmospheric conditions at the facility. The frequency of thunderstorms, icing, and dust must be considered in selecting specific sensors and designing the sensor installation. Consideration must also be given to the electrical power supply for the instrument system. Where power interruptions are frequent, an uninterruptable power supply should be included in the system and an alternate source of power should be available.

Specific information on meteorological measurements that is appropriate at low-level waste sites has been published by the NRC in Regulatory Guide 1.23 (NRC 1974) and in a more recent draft Regulatory Guide (Task ES 401-4) for uranium recovery facilities. The ANS and ANSI provide more detailed information (ANSI 1984). The EPA has also provided guidance on meteorological measurements (EPA 1987). The following sections are based on the NRC and ANSI guidance. EPA guidance differs from the NRC and ANSI guidance in a few areas.

B.3.1 Measured Parameters

Wind measurements should be made at a sufficient number of levels to adequately characterize the wind at potential release heights. At a minimum, wind measurements should be made at a height of 10 m.

If a vertical temperature difference is used to characterize atmospheric stability, the temperature difference should be determined over an interval of sufficient thickness to resolve accepted stability classes. A 50-m thickness has been held acceptable (NRC 1974; ANSI 1984) for this purpose. For surface releases, the NRC (1974) and ANSI (1984) recommend measurement of the temperature difference between 10 and 60 m. If releases are to be made through stacks that are taller than 60 m, they suggest that the temperature difference between the release height and the 10-m height be determined.

Other meteorological measurements as may be required should be made using standard instrumentation in accordance with accepted procedures. Standard meteorological measurement techniques are described by Mason and Moses (1984), and accepted procedures are outlined in ANSI/ANS-2.5-1984 (ANSI 1984).

B.3.2 Instrument Mounting

Wind and temperature instruments mounted on towers may be placed on top of the towers or on booms extending to the side of the towers. If instruments are mounted above a tower, they should be mounted on a mast extending at least one tower diameter above the tower. If the instruments are mounted on booms extending to the side of a tower, the booms should be oriented in directions that minimize the potential effects of the tower on the measurements. The instruments should be at least two tower diameters from the tower, while three to four tower diameters is desirable. The orientation of booms for wind instruments should be determined after considering the frequencies of all wind directions. Orientation of the booms on the basis of only the prevailing direction may not minimize tower effects. In some locations it may be necessary to place wind instruments on opposite sides of the tower to obtain reliable wind data for all wind directions. Temperature sensors should be placed in aspirated radiation shields, and the shields should be oriented to minimize effects of direct and reflected solar radiation.

B.3.3 Measurement Recording Systems

An onsite meteorological measurement system should include two separate data recording systems, and at least one of the systems should be digital. The other recording system may be digital or analog. In addition, the output of the instruments should be displayed in a location where instrument performance can be monitored on a regular basis.

Digitally recorded data, except for sigma theta and precipitation, should be averages based on at least 30 samples taken at intervals not to exceed 60 sec. The time period represented by the averages should not be less than 15 minutes. A minimum of 180 instantaneous wind direction samples are required for estimation of sigma theta and sigma phi. If strip charts are used as one of the recording systems, continuous trace strip charts should be used for wind data; multipoint strip chart recorders may be used for the remaining data. If properly located, the strip charts may be used for the data displays.

B.4 MEASUREMENT SYSTEM ACCURACY

The accuracies of the monitoring measurements should be consistent with the specifications set forth in either ANSI/ANS-2.5-1984 (ANSI 1984), the version of ANSI/ANS-2.5 that is current when the monitoring system is designed, or guidance provided by EPA if the EPA guidance recommends more stringent specifications. System accuracy standards for digitally recorded data and instrument specifications contained in ANSI/ANS-1984 include:

Wind direction	±5° in azimuth with a starting threshold of 0.45 m/sec (1 mph); if the sensor is to be used to determine sigma theta, the damping ratio must be between 0.4 and 0.6, and the delay distance must not exceed 2 m
Wind speed	±0.22 m/sec (0.5 mph) for speeds less than 2.2 m/sec (5 mph); within 10% for speeds of 2.2 m/sec or greater, with a starting speed of less than 0.45 m/sec
Temperature	±0.5°C
Temperature Difference	±0.15°C/50 m
Precipitation	±0.25 mm (0.01 in.) resolution, and within 10% for totals greater than 5 mm (0.2 in.)
Time	±5 min

For analog data recording systems, the allowable error limits for wind direction and speed are increased by 50%, and the acceptable error in time is increased to 10 minutes.

B.5 INSPECTION, MAINTENANCE, AND CALIBRATION

The meteorological monitoring program should provide for routine (daily or weekly) inspection of the data, and scheduled maintenance and calibration of the meteorological instrumentation and data-acquisition system. Inspections, maintenance, and calibrations should be conducted in accordance with written procedures, and logs of the inspections, maintenance, and calibrations should be kept and maintained as permanent records. All systems should be calibrated semiannually, unless system performance indicates that more frequent calibrations are necessary.

The instrument system should provide joint data recovery of at least 90% on an annual basis for wind direction, wind speed, atmospheric stability, and other meteorological elements required for dose assessment. Data recovery rates for other meteorological elements should be 90% on an annual basis.

B.6 SUPPLEMENTARY INSTRUMENTATION

The topographic setting of a facility and the distances from the facility to points of public access should be considered when evaluating the need for supplementary instrumentation. If meteorological measurements at a single location cannot adequately represent atmospheric conditions for transport and diffusion computations, supplementary measurements should be made. Full meteorological instrumentation is not required at a supplementary location. Supplementary instruments need only measure those elements that have significant spatial variation.

B.7 DATA SUMMARIZATION AND ARCHIVING

Data used in dose assessments should be collected as 15-minute averages for use in emergency response applications. The 15-minute averages can be combined into hourly averages for use in consequence assessments. The 15-minute data should remain readily available in a temporary archive for at least 24 hours. Then either the 15-minute or hourly averages should be stored for entry into a permanent archive and climatological summarization. These data should be examined and entered into the permanent archive at least monthly. Storage of the 15-minute or hourly data is necessary to develop an adequate data base for use with new assessment tools as they are developed. More frequent examination of the hourly data to detect problems in meteorological instrumentation or in the data acquisition system is recommended. Further guidance in meteorological data collection, processing, and archiving is presented by Crutcher (1984) and in various EPA documents (e.g., EPA 1986; Finkelstein et al. 1983).

B.8 METEOROLOGICAL DATA PROCESSING

Designing environmental surveillance programs, establishing compliance with regulations, and analyzing the consequences of potential or actual releases require information on a common set of meteorological elements. Typically, these elements are wind direction, wind speed, air temperature and temperature gradient, and mixing layer thickness. Although the individual applications may require data for a common set of meteorological elements, the format in which the data are required will vary by application and assessment procedure.

Consequence analyses for potential routine releases should be based on climatological data because the meteorological conditions at the time of release are unknown. If the postulated release is continuous, the analyses should be made using a joint frequency distribution of wind direction, wind speed, and atmospheric stability based on data from at least one annual cycle. When possible, the frequency distributions should be based on 5 or more years of data. This approach may also be used for intermittent releases provided that the releases will occur randomly and with sufficient frequency to make the use of an annual frequency distribution appropriate.

Consequence analyses for postulated accidental releases should be made for each downwind direction using conservative meteorological assumptions for each release scenario. For a ground-level release, these assumptions will include a low wind speed and stable atmospheric conditions; for elevated releases, a range of conditions should be evaluated because a moderate wind speed and neutral atmospheric conditions may be more conservative than a low wind speed and stable conditions. Straight-line Gaussian models are appropriate for assessments of postulated releases. Trajectory models may also be used if adequate data are available. The joint frequency distribution and choices of meteorological conditions for the accident analyses should be based on a minimum of 2 years of hourly averaged data. However, if offsite data are used, the analyses may be based on 2 or more years of hourly observations made with well-maintained instrumentation.

Consequence analyses for actual routine releases and demonstrations of compliance may also be made using climatological summaries, provided that a straight-line model is appropriate. Climatological summaries used in the evaluation of consequences of an actual release should be based on hourly data for the specific period of the release. For example, if a continuous release occurs from May 15 through June 26, the joint frequency distribution should be based on the meteorological observations during that period. Where straight-line models are inappropriate, consequence assessments for routine releases and demonstrations of compliance should be made using a time series of hourly average data. These time series should include all supplementary data required to account for spatial as well as temporal variations in atmospheric conditions.

Consequence assessments during the course of an emergency should be based on time series of actual and forecast atmospheric conditions. When necessary, data should be included in the time series to represent spatial variations in the atmospheric conditions. An averaging interval of 15 minutes has been accepted by the NRC as appropriate for data used in emergency response applications. This interval is consistent with the averaging interval specification in ANSI/ANS-2.5-1984 (ANSI 1984). Instantaneous observations are too variable to be used with confidence, and hourly averaged values do not reflect changes in conditions in a timely manner for emergency response applications.

Assessment procedures have varying meteorological data needs and a precise format in which the meteorological data must be entered. The data needs and format for AIRDOS-EPA are set forth in Moore et al. (1979). Data needs for other EPA models are set forth in the individual documentation of the specific models and are summarized in EPA (1986). In addition to EPA models, there are DOE, NRC, and proprietary models that may be appropriate for consequence assessments. Data requirements for these models must be determined from model documentation.

B.9 REFERENCES

American National Standards Institute (ANSI). 1984. American National Standard for Determining Meteorological Information at Nuclear Power Sites. ANSI/ANS 2.5-1984, American Nuclear Society, La Grange Park, Illinois.

Barr, S., and W. E. Clements. 1984. "Diffusion Modeling: Principles of Application." In Atmospheric Science and Power Production. DOE/TIC-27601, U.S. Department of Energy, Washington, D.C.

Crutcher, H. L. 1984. "Monitoring, Sampling, and Managing Meteorological Data." In Atmospheric Science and Power Production. DOE/TIC-27601, U.S. Department of Energy, Washington, D.C.

Finkelstein, P. L., D. A. Mazzarella, T. J. Lockhart, W. J. King, and J. H. White. 1983. Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Gifford, F. A. 1961. "Use of Routine Meteorological Observations for Estimating Atmospheric Dispersion." Nucl. Safety 3(4):76-80.

Gifford, F. A. 1968. "An Outline of Theories of Diffusion in the Lower Layers of the Atmosphere." In Meteorology and Atomic Energy - 1968. TID-24190, U.S. Atomic Energy Commission, Washington, D.C.

Gifford, F. A. 1976. "Turbulent Diffusion-Typing Schemes: A Review." Nucl. Safety 17(1):68-86.

Hanna, S. R., G. A. Briggs, J. Deardorff, B. A. Egan, F. A. Gifford, and F. Pasquill. 1977. "AMS Workshop on Stability Classification Schemes and Sigma Curves--Summary of Classification Recommendations." Bull. Am. Meteorol. Soc. 58:1305-1309.

Horst, T. W., J. C. Doran, and P. W. Nickola. 1979. Evaluation of Empirical Atmospheric Diffusion Data. NUREG/CR-0798, U.S. Nuclear Regulatory Commission, Washington, D.C.

Irwin, J. S. 1980. Dispersion Estimate Suggestion #8: Estimation of Pasquill Stability Categories. Docket Reference No. II-B-10, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Irwin, J. S. 1983. "Estimating Plume Dispersion--A Comparison of Several Sigma Schemes." J. Climate Appl. Meteorol. 22:92-114.

Lague, J. S., E. M. Irvine, and T. F. Lavery. 1980. "Validation of Alternate Turbulence Typing Models for Estimating Air Quality Effects of Coastal Sources Near Rough Terrain." Presented at the Second Joint Conference on Applications of Air Pollution Meteorology, and the Second Conference on Industrial Meteorology, New Orleans, Louisiana.

Lalas, D. P., V. Catsoulis, and M. Petrakis. 1979. "On the Consistency of Stability Classification Schemes when Applied to Non-Homogeneous Terrain." Atmos. Environ. 13:687-691.

Luna, R. E., and H. W. Church. 1972. "A Comparison of Turbulence Intensity and Stability Ratio Measurements to Pasquill Stability Classes." J. Appl. Meteorol. 11:663-669.

Mason, C. J., and H. Moses. 1984. "Meteorological Instrumentation." In Atmospheric Science and Power Production. DOE/TIC-27601, U.S. Department of Energy, Washington, D.C.

Mitchell, A. E., Jr. 1982. "A Comparison of Short-Term Dispersion Estimates Resulting from Various Atmospheric Stability Classification Schemes." Atmos. Environ. 16:765-773.

Moore, R. E., C. F. Baes, III, L. M. McDowell-Boyer, A. P. Watson, F. O. Hoffman, J. C. Pleasant, and C. W. Miller. 1979. AIRDOS-EPA: A Computerized Methodology for Estimating Environmental Concentrations and Dose to Man from Airborne Releases of Radionuclides. EPA 520/1-79-009, U.S. Environmental Protection Agency, Washington, D.C.

Pasquill, F. 1961. "The Estimation of the Dispersion of Windborne Material." Meteorol. Mag. 90(1063):33-49.

Pasquill, F. 1979. "Atmospheric Dispersion Modeling." J. Air Poll. Control Assoc. 29:117-119.

Petersen, W. B., J. A. Catalano, T. Chico, and T. S. Yuen. 1984. INPUFF - A Single Source Gaussian Puff Dispersion Model User's Guide. EPA-600/ 8-84-207, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Powell, D. C., H. L. Wegley, and T. D. Fox. 1979. MESODIF-II: A Variable Trajectory Plume Segment Model To Assess Ground-Level Air Concentrations and Deposition from Nuclear Power Facilities. NUREG/CR-0523, U.S. Nuclear Regulatory Commission, Washington, D.C.

Ramsdell, J. V., G. F. Athey, and C. S. Glantz. 1983. MESOI Version 2.0: An Interactive Mesoscale Lagrangian Puff Dispersion Model With Deposition and Decay. NUREG/CR-3344, U.S. Nuclear Regulatory Commission, Washington, D.C.

Randerson, D. 1984a. "Atmospheric Boundary Layer." In Atmospheric Science and Power Production. DOE/TIC-27601, U.S. Department of Energy, Washington, D.C.

Randerson, D. 1984b. "Power Production and the Atmosphere." In Atmospheric Science and Power Production. DOE/TIC-27601, U.S. Department of Energy, Washington, D.C.

Regulatory Guide 1.23 (1974); "Onsite Meteorological Programs." U.S. Nuclear Regulatory Commission, Washington, D.C.

Regulatory Guide Task ES 401-4 (Draft 1985); "Onsite Meteorological Measurement Program for Uranium Recovery Facilities - Data Acquisition and Reporting." U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Washington, D.C.

Scherpelz, R. I., T. J. Bander, G. F. Athey, and J. V. Ramsdell. 1986. The MESORAD Dose Assessment Model. NUREG/CR-4000, U.S. Nuclear Regulatory Commission, Washington, D.C.

Sedefian, L., and E. Bennett. 1980. "A Comparison of Turbulence Classification Schemes." Atmos. Environ. 14:741-750.

Skaggs, D. L., and E. Robinson. 1976. "A Comparison of Methods for Estimating Atmospheric Stability and Diffusion Coefficients." J. Air Poll. Control Assoc. 26:888-891.

Slade, D. H., ed. 1968. Meteorology and Atomic Energy - 1968. TID-24190, U.S. Atomic Energy Commission, Washington, D.C.

Turner, D. B. 1964. "A Diffusion Model for an Urban Area." J. Appl. Meteorol. 3:83-91.

Turner, D. B. 1969. Workbook of Atmospheric Dispersion Estimates. PHS Publication No. 999-AP-26, U.S. Department of Health, Education, and Welfare, Cincinnati, Ohio.

U.S. Environmental Protection Agency (EPA). 1986. Guideline on Air Quality Models (Revised). EPA-450/2-78-027R, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Environmental Protection Agency (EPA). 1987. On-Site Meteorological Program Guidance for Regulatory Modeling Applications. EPA 450/4-87-013, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Weil, J. C. 1979. "Applicability of Stability Classification Schemes and Associated Parameters to Dispersion of Tall Stack Plumes in Maryland." Atmos. Environ. 13:819-831.

APPENDIX C

GROUND-WATER AND SURFACE-WATER MONITORING PROGRAMS

APPENDIX C

GROUND-WATER AND SURFACE-WATER MONITORING PROGRAMS

Ground-water and surface-water environmental monitoring programs are needed at LLWDFs to demonstrate compliance with applicable federal, state, and local laws, regulations, and orders. The data should be representative of the conditions at the various LLWDFs, ensuring that the best water samples are collected in a credible, uniform, and well-documented manner. The data will be used to assess the transportation, diffusion, and deposition of various contaminants that are released to the environment by the facility.

Each LLWDF needs to establish a ground-water and surface-water monitoring program that is appropriate to the activities at the site. The program must take into account the activities at the site, the topographical characteristics, surface drainage systems, geology, ground-water hydrology, and the distance to various critical discharge points. The scope of the program should be based on an evaluation of the ground-water and surface-water data needed to determine the impact assessments, environmental surveillance needs, and emergency response requirements. In addition, the monitoring program should be documented according to the guidelines outlined in this Appendix.

The ground-water monitoring program should be based on known leaching or disposal of waste to the land surface in a liquid or solid form. A clear understanding of the subsurface hydrology and geology is therefore required, along with careful selection of the contaminants to be monitored. The monitoring system must aid in determining:

- background water quality
- the rate of ground-water flow
- the direction of ground-water flow
- if contamination has reached the ground water
- if the contamination is the result of a one-time occurrence, a continuing operation, or from past operations.
- the extent to which the contaminant has migrated
- the potential areas threatened by the contamination.

Because ground water travels slowly, the monitoring program may be in operation years after the operation at the facility has been completed.

The basis for developing a surface-water monitoring program is the need to preserve water for domestic and agricultural use. Contamination generally does not occur directly to a surface-water body unless some unusual occurrence happens, such as a waste being dumped directly into the surface water. The most common type of contamination occurs from storm runoff or surface drainage from a facility. Surface water is also contaminated by the seepage of contaminated ground water into the surface-water body. Storm runoff usually results in a high level of contaminants reaching the surface-water body for a short time period. Once the storm has passed, flow of the stream will dilute contamination to or below previous levels. Surface drainage from a facility and contaminated ground water reaching a stream may create long-term pollution problems. As a result, the level of the concentration of contaminants in the stream may remain elevated for extended periods of time and require remedial action. The identification of the source of contamination is required before an assessment of the impact on the surface water can be performed.

There are a large number of ground-water and surface-water regulations that have been established by state and federal agencies. The following is a brief summary of the federal laws which may apply to LLWDFs:

- SDWA - The Safe Drinking Water Act was passed in 1974 to set limits for certain chemicals in water that is used for consumptive purposes. This act became effective on June 24, 1977, and has been used not only for drinking-water sources, but other uses of water.

- FWPCA - The Federal Water Pollution Control Act Amendments of 1972 was designed to require the U.S. Environmental Protection Agency to create a list of toxic pollutants and establish limits and guidelines for their control. The primary list was to contain the "priority pollutants," a list of the elements and compounds found to be toxic.

- Executive Order 12088, was established in 1978 and requires that federal agencies comply with state pollution regulations. The state laws must be as stringent as the existing federal law.

C.1 MONITORING REQUIREMENTS

Water sampling at LLWDFs involves ground, vadose zone, and surface sources. This section addresses the monitoring requirements in each of these regions, including the installation of monitoring wells, and provides a general discussion of the available sampling methods. Later sections of this appendix include more detailed information on ground-water measurements and sampling procedures, followed by a separate section on quality control and statistical analyses.

C.1.1 Ground Water

A systematic network of monitoring wells is required to have an acceptable ground-water monitoring program. To design the network, an understanding of several factors is required. These factors include: climate, soil types, depth to water, geologic information, hydrologic information, and expected contaminants in the ground water resulting from facility operation. This information will contribute to the understanding of which contaminant moves with the ground water, where it is moving, and how fast it is moving (Rich 1980). Because each site is unique, the system must be designed based on site-specific conditions.

There are many published documents that describe the design and installation of monitoring wells. Therefore, a detailed set of guidelines is not included in this Appendix.

C.1.1.1 Design

When designing a monitoring system, it is important to have a planning phase to ensure that the system will perform as required. The plan should include:

- a statement of the objectives of the monitoring system as it relates to regulatory requirements
- a definition of the total area of interest, vertically and horizontally
- an inventory of existing ground-water use and discharge points to springs and surface water
- an estimate, based on existing data, as to the duration of the monitoring program
- a list of goals, objectives, milestones, and critical points
- an established quality assurance program that includes, but is not limited to, the criteria for work and various reviews required to assess the progress of the monitoring system.

There are two primary requirements that must be met to establish a meaningful monitoring system. The characteristics of the flow field, including geology, structures, geometry, and hydrologic characteristics in the steady-state (natural) mode, as well as the nonsteady-state (stressed) mode, must be understood. To accomplish the above, it is recommended that the following work be performed.

A field survey of the area should be conducted that includes the geology, surface-water drainage systems, existing wells, and other hydrologic conditions. If possible, the direction of the ground-water movement, direction of flow, and rate of flow should be determined. Geologic units that are capable of transmitting ground water and units that are impermeable should also be determined. In addition, tectonic features such as faults that are conduits for the migration of ground water or that work as aquitards, preventing ground-water movement, should be identified. The surface-water drainage system should be mapped, because ground water comes to the surface through wells or discharges to the environments via springs and seeps into surface-water bodies of water.

If sufficient data are not available from existing wells, it is recommended that surface geophysical techniques or exploratory boreholes be used. The advantage of borehole exploration is that these wells may be used as future monitoring wells, if they are properly located.

Because the facilities will not be placing the contaminated material directly into the saturated zone, it is important to understand the vadose zone (unsaturated zone). Information about the unsaturated zone can be obtained from outcrops or by exploratory drilling. Important items include the chemical composition of the rock material, the hydraulic characteristics, and the moisture content. Vadose zone samples are analyzed for hydraulic characteristics in the laboratory. Details on the collection and analysis of soil samples can be found in Section A.2.4 of Appendix A.

C.1.1.2 Monitoring Wells

The areal distribution of monitoring wells is not only controlled by the plan used to determine the degree of contamination at various points around the facility, it must also be controlled by regulatory requirements and economics. The Resources Conservation and Recovery Act requires that a minimum of one upgradient well and three downgradient wells be installed around a facility. The monitoring system should provide an early warning of ground-water pollution, both laterally and vertically. The system must also provide adequate information for the assessment, concentration, dispersion, and movement of the contaminant toward a discharge point (Diefendorf and Ausburn 1977).

Upgradient monitoring wells are useful in providing background water quality information. These data are useful in the determination of the quantity of contaminants being contributed to the ground-water system from other sources. In determining the location of upgradient wells, it is important to take into consideration the topography of the area and the surface-water stream and lake systems. It is also important to monitor streams in an upgradient direction to determine if contaminants observed in downgradient wells may be showing the influence of contaminated surface water infiltrating into the ground water. Upgradient wells must be located far enough away from the disposal facility so that the radius of influence of the well, when it is pumped, does not reverse the ground-water gradient. The radius of influence can be determined before the facility begins operation or by the use of data such as the hydraulic conductivity and storativity of the saturated aquifer.

Wells located within or near the disposal area provide a very early warning as to which contaminants are reaching the ground water and in what degree of concentration. This gives the operator of the facility the opportunity to modify the operation and take corrective measures, as required. Additionally, wells within or near the disposal area aid in the determination of the hold-up time within the vadose zone. A determination can be made following the start-up of a facility and the time that a contaminant first reaches the saturated zone, which allows the operator to modify the operation to obtain an optimum hold-up time for contaminants or complete hold-up within the vadose zone.

Wells that are located downgradient will provide information on the geometry of contaminants that may be advancing from the disposal site to a discharge point. They will also indicate areas into which the contaminant has not migrated. Because the concern is to prevent contaminants from migrating offsite, emphasis should be placed on these wells with respect to sampling and analysis. As data from downgradient wells are used to delineate the existence of contaminant plumes in the ground water, the locations of the wells should be reviewed. If it is determined that the system needs to be modified to ensure that the flow rate and direction is clearly understood, additional wells will be required. One method for the installation of additional wells is the alignment of several wells parallel to the inferred direction of the contaminant movement, downgradient of the contaminant plume and upgradient from a potential discharge point. These wells should be monitored in such a manner as to detect the earliest sign of the advancement of the contaminant plume. Because the geology and hydrology of a ground-water system is almost never static, additional wells are sometimes necessary to obtain further information on the migration of contaminants. The need for additional wells should be in the planning documents.

There are several ways to construct monitoring wells to obtain a representative sample from the ground water (EPA 1975; Cherry 1983; Johnson Division 1980; Todd et al. 1976; USATHMA 1982). The two major concerns of a monitoring well are the collection of representative samples and the ability to stress the well in order to obtain hydrologic information such as hydraulic conductivity and storativity (Cherry 1982; Gibb et al. 1981; Jackson and Patterson 1982; Pickens and Grisak 1979; Pickens et al. 1981). Several of these documents describe the construction and sampling of monitoring wells (Korte and Kearl 1984; Kruseman and DeRidder 1979; LeGrand 1968; Scalf et al. 1981; Todd et al. 1976); therefore, detailed information on construction of wells is not included in this document.

C.1.1.3 <u>Sampling Methods</u>

There are several types of equipment used to collect samples from monitoring wells. These include bailers, as well as suction, submersible, airlift, bladder, and positive displacement pumps (Johnson Division 1980). A brief discussion of each type is provided in this section.

Bailers - This method of sampling has existed for a very long time. Early bailers were nothing more than a bucket tied to a length of rope. They have now progressed to an inert material with a ball valve in the base and a vented cap at the top. The method of lowering the device into the well still consists of a rope or wire rope. There are several advantages to the bailer: 1) it is inexpensive, 2) no power source is required, and 3) it is easy to build and operate. The major disadvantages of the bailer include: 1) cross-contamination is a potential problem, if used in more than one well, 2) it may cause aeration of the sample, 3) it may be sampling the water column, and 4) it may knock material off the casing into the water being sampled.

Suction pumps - There are several suction type pumps available, all of which produce a good sample, if volatiles are not of concern. The pump works by creating a low pressure, into which the water flows. This is done by a centrifugal vane pump or by the smaller peristaltic type pump. There are two major advantages of this type of pump and these are: 1) the small pumps are relatively portable, and 2) this type of pump is relatively inexpensive.

Some of the disadvantages of this type of pump are: 1) a limited lift capability, 2) the volume decreases with depth, 3) degassing occurs with the decrease of pressure.

Submersible pump - The difference between this pump and the "normal" turbine type pump is that the motor is attached directly to the impellers below the water level. The motor is housed in a waterproof casing and only the column and wires return to the surface. The advantages of this type of pump are: 1) it produces a large volume of water, 2) it can pump at greater depths, and 3) it has low motor maintenance. Some of the disadvantages are: 1) it requires a power source, 2) it will cross-contaminate if used in more than one well, and 3) it degasses the sample when samples are not collected under pressure.

Air-Lift Method - This method injects air or gas into the well and forces the sample out of the well by displacement. The advantages of this type of system are: 1) it is very portable, 2) it can obtain a sample from greater depths, 3) it is not an expensive system, 4) it is easy to install, and 4) it has no decontamination problems, because the water transport system remains in the well. Some of the disadvantages are: 1) the air mixes with the sample, which can change the chemical characteristics of the sample, and 2) the air strips are volatile. This system is not recommended because of the effect on the chemical parameters of the sample.

Positive displace pump - This type of pump, once called the "sucker" pump, is still in use today. The pump consists of a series of rods that are attached to a valve that opens and closes on an up-and-down stroke. The pump can work at great depths and produce moderate amounts of water. The advantages of the pump are: 1) it collects a representative sample, 2) it is moderate in cost, 3) it does not strip the sample, 4) it can be built from various types of material, and 5) it lifts from depths over 200 feet. Some of the disadvantages are: 1) it requires a well greater than 2 inches in diameter, and 2) cross-contamination is possible if it is used for more than one well.

Bladder pump - This type of pump consists of a chamber and a bladder. The chamber is allowed to fill with water, a check valve is closed, and the bladder is inflated with air, forcing the water to the surface. The advantages of this type of pump are: 1) no air/water contact exists, 2) it can be pumped dry, and 3) it can be constructed from a variety of material. Some of the disadvantages are: 1) it has a slow pumping rate, 2) it requires large volumes of air to operate over extended period of time, and 3) it is difficult to decontaminate between samples.

C.1.2 Vadose Zone

Vadose water occurs in three subdivisions of a soil column, including the soil-water zone, the intermediate vadose zone, and the capillary zone. Within these zones, the water within the pore spaces is impacted by different processes. In the soil-water zone, which exists between the ground surface and the bottom of the major root zone, water exists only as a result of excessive precipitation in the form of rain or irrigation. The thickness of this zone varies with soil type and vegetation. Therefore, this zone is highly important when reviewing agricultural requirements for crops. The amount of water in this zone is controlled primarily by the surface air temperature. Hot arid conditions tend to remove much of the water, leaving only a film of moisture around the grains. In a temporal area, the excess water moves downward by gravitational influences.

The intermediate vadose zone extends from the bottom of the root zone to the upper edge of the capillary zone. This zone may also vary, based upon the seasons, irrigation, or other factors that affect the level of the saturated zone. This zone contains water that originated from the soil-water zone, as a result of gravitational influences, and from the capillary zone, as a result of water level fluctuation and hygroscopic forces.

The last zone is the capillary zone, which extends from the saturated zone up to the limit of capillary action. Water in this zone is in equilibrium between surface tension of the water and the weight of the water. The thickness of the zone will vary with the inverse of the pore size of the soil or rock.

There are basically two methods for measuring and sampling vadose water. A tensiometer will measure the pressure changes in the vadose zone, which can be interpreted as changes in water volume and a pressure-vacuum lysimeter. The lysimeter requires that a porous ceramic cup be set at depth and a vacuum be applied to move water to a lower pressure point (Kennedy et al. 1974; Parizek and Lane 1970).

Methods for the installation of lysimeters are covered in other documents and will not be discussed in this appendix.

C.1.3 Surface Water

The sampling of surface water can be from swiftly flowing streams to ponds, springs, and seeps. As in the ground-water section, on a flowing stream there needs to be an upgradient sampling point and at least one downgradient sampling point (Jaffee et al. 1982; GAO 1981). Springs and seeps should also be sampled in the upgradient direction, as well as in the downgradient direction. Springs and seeps upgradient will represent the ground water not impacted by the facility operation, and springs and seeps downgradient will represent the ground water impacted by the facility or downgradient surface-water sources that are contributing to the ground water. Lakes and ponds, unless their bottom is sealed by clay, generally are a surface representation of the ground water.

There are two basic methods of collecting surface-water samples, the "grab" method and the use of a pump. The "grab" sample method consists of dipping a collection vessel into the water and allowing it to fill. There are several difficulties with this method. Two major problems are that the filtering must take place at the laboratory and that samples cannot be preserved without adding the preservative to the sample. The major advantage of "grab" sampling is that it is inexpensive (Brown et al. 1970).

The pumping method, partially with flow-proportioning included, gives a sample that is more representative of the stream over time. The pump allows for the installation of a filter into the system and preservatives can be added to the sample bottle before the sample is collected.

C.2 MONITORING METHODS AND PROCEDURES

Equipment that is generally required to perform the collection of water samples will be controlled primarily by the depth to water and the analysis that must be performed on the sample. For example, if a sample is only to be analyzed for radiological constituents that are not affected by pressure changes, a submersible pump will be adequate. If however, volatile organics are to be collected, a method that does not strip the volatile from the sample must be used. Regardless of the sampling method, it is recommended that permanent installations be considered for long-term monitoring (Casey et al. 1983). This will reduce the possibility of cross-contamination and handling of equipment. All equipment should be constructed from material (i.e., Teflon,® stainless steel) that will not leach into the water or attract contaminants.

The art of sample preservation has been changing constantly and there are many articles and papers that describe the methods. The conclusion that has been reached is that there is no ideal method to preserve samples. When a sample is collected, it is impossible to maintain that sample in the same condition as it existed in the stream, well, seep, or spring. Therefore, any method of preservation is a compromise and care must be taken to assure that the objectives for which the sample was collected are met. Further guidance on how to preserve samples can be found in one or more of the following publications related to sample preservation:

- The EPA published a comprehensive list of preservation techniques in 1979 (EPA 1979a). This document is one of the most widely used references in the country. However, it has been criticized by the General Accounting Office (GAO). The GAO's primary concern is the difficulty in getting samples to the laboratory for analysis within a time frame that will assure sample freshness.

- The EPA has also published a document on the procedures for measurement of radioactivity in drinking water. This document lists which radionuclides require acidification with nitric acid and which require no preservatives. The document was published in 1980 as Prescribed Procedures for Measurement of Radioactivity in Drinking Water (EPA 1980).

- The National Handbook of Recommended Methods for Water Data Acquisition (USGS 1977) provides extensive information on how to collect water samples. This document indicates that the method of preservation depends upon the analytical method to be used to analyze the sample. It was criticized by the GAO for not prescribing a method for logistically handling the sample from collection to analysis, within an allotted time.

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- The American Public Health Association (APHA), The American Water Works Association, and The Water Pollution Control Federation jointly published a document that addresses the need for preservation of samples. The document was published in 1980 as Standard Methods for the Examination of Water and Wastewater (APHA 1980).

- The American Society for Testing and Materials (ASTM) included in their Annual Book of Standards (ASTM 1979) a brief discussion on the preservation of water samples.

C.2.1 Water Sampling Procedures

The sampling of surface water and ground water has in the past been very site-specific. However, there is included in this appendix a detailed, step-by-step description of the water sample procedures. These procedures describe the techniques that may be used in obtaining both surface-water and ground-water samples. These techniques include grab sampling for surface-water testing and sampling from bailers, positive displacement pumps, and submersible pumps for ground water. These procedures also describe some ground-water field measurement procedures including: water level, temperature, specific conductivity, and pH. Also, documentation, storage, and chain-of-custody for samples are discussed (Nelson and Ward 1981; Langmuir 1971).

C.2.1.1 Surface Water

Grab samples will generally be taken when sampling surface water from ponds, streams, springs, or seeps, unless the constituents of interest require different sampling procedures.

Equipment

The following equipment may be needed in collecting grab samples from ponds or streams:

Sample bottles (with labels prefixed)
Sample seals
Field record from chain-of-custody forms
Indelible marker
Radiation detection equipment
Rubber gloves
Rubber boots
Protective clothing
Bucket (stainless steel or Teflon®)
Funnel (glass or Teflon®)

Procedure

a. Record the sampling number, location, date, and time on the field record form.

b. Follow appropriate radiation work procedures when collecting the samples.

c. Always wear rubber gloves when collecting the samples.

d. Collect the water sample using the bucket, observing the following guidelines.

   - If the sample is to be analyzed for volatile organics (VOA), a bucket should not be used. Instead, the VOA vials should be filled directly at the surface-water sampling location.

   - Avoid hitting or agitating the bottom, which resuspends the sediments.

   - If sampling from a stream, avoid stagnant areas.

   - Avoid areas of heavy surface debris.

e. Transfer the water from the bucket to the sample bottle, using the funnel, taking care to avoid spilling onto outside of bottle.

f. Record the sample number and date on the sample label and place on bottle.

g. Complete the chain-of-custody form.

h. Follow chain-of-custody procedures.

C.2.1.2 Ground Water

Ground-water sampling is more complex than surface water in that additional information is required along with the sample. This additional information includes the need for water level, temperature, conductivity, and pH measurements (Jackson and Patterson 1982; Korte and Ealey 1983). Hence, a discussion of each of these ground-water measurement and sampling procedures is provided in the separate subsections that follow.

C.2.2 Water Level Measurements

Water level measurements can be made using any of the several methods described in the following subsections. Because these measurements involve recording the depth to water from the land surface, the following equipment should be available prior to initiating the measurements:

Steel measuring tape with attached weight
Blue carpenters chalk
Electric tape (E-tape)
Engineers measuring tape
Field record forms.

C.2.2.1 Graduated Steel Tape Procedure

An E-tape should be used to measure approximate depth to water to estimate the hold point for the steel tape. The steel tape should be used to measure the exact depth to water.

a. Lower the E-tape from the measuring point into the borehole until the buzzer and the light indicate contact with the water.

b. Mark the E-tape at the measuring point. Because E-tapes are usually marked in 1-foot increments, an engineer's measuring tape must be used to measure to nearest tenth of a foot.

c. Chalk the 1-foot section of the steel tape below the zero measuring point.

d. Lower the steel tape from the wells measuring point to the estimated water level (determined by the E-tape). Note the amount of tape that is in the well by reading the tape at the measuring point. This value is referred to as the hold point.

e. Remove the steel tape and check the wetted portion below the zero reading point. If the chalked portion is not wet, repeat the procedure, but allow more of the tape to go down the well (i.e., use a greater hold point).

f. Add the unwetted length of the chalked portion of the tape to the hold point to obtain the depth-to-water measurement.

g. Repeat this procedure until two steel tape measurements agree within 0.05 feet.

h. Record the depth-to-water measurements, time of measurement, measuring device (and serial number), and the name of the person taking the measurement on the field record form.

C.2.2.2 <u>Pressure Transducer Method</u>

A pressure transducer can be used to take continuous head measurements. It consists of a pressure-sensitive transducer that is connected via a cable to a control box and data recording device. When lowered below the water level in a well, the transducer measures the pressure of the overlying water column. This measurement is converted to units of feet by the control box and is recorded at the desired time interval by the data recorder.

Pressure transducers vary somewhat according to manufacturer, so a detailed procedure will not be presented here. The owners' manual should be consulted for details. Listed below are some basic steps that can be applied with any transducer:

1. The transducer should be checked to see if it is working properly before it is used in the field. This can be done by applying a small pressure to it (such as submersing the probe in a container of water) and observing its response.

2. Make sure that the pressure transducer will operate over the appropriate pressure range for the test.

3. Record the borehole or well number; monitored hydrologic unit; make, range, model, and serial number of the pressure transducer; atmospheric pressure (this may be done after the test if the time of the probe reading is noted and the second reading can be interpolated to the same time); transducer pressure before and after installation; depth; water level (measured with a steel tape); steel tape number; time; list of any attached data; comments; and name of installer and reviewer (if any).

C.2.3 Temperature Measurements

Temperature measurements are taken during and after purging of the well, just prior to sample collection. Measurements taken during purging are used to help determine if the well bore has been sufficiently evacuated, as indicated by stabilization of temperature. The temperature is considered stable when two consecutive measurements agree within 0.2°C. The final temperature measurement is taken just prior to sampling and is recorded as an analytical value for the sample. The digital thermometer should occasionally be checked against a standard (freezing or boiling point of water) and/or a standard thermometer for accuracy.

Equipment

The following equipment will be needed:

Digital thermometer
Field record forms.

Procedure

a. Turn on the digital thermometer. Make sure that the switch is positioned so that the measurements will be in degrees centigrade.

b. Place the probe into the stream of water being discharged from the pump.

c. The temperature is indicated by a flashing display, which will normally fluctuate for a few seconds. Wait until the fluctuation ceases (i.e., until the same temperature is indicated on three consecutive flashes), and then record the temperature on the field record form.

C.2.4 Specific Conductivity Measurements

Conductivity measurements are taken during and after purging of the well, just prior to sample collection. Stabilization of conductivity measurements during purging is an indicator that the well bore has been sufficiently evacuated. Conductivity is considered stable when two consecutive measurements agree within a variance of 5%. The final conductivity measurement is taken just prior to sampling and is recorded as an analytical value for the sample. The conductivity meter should be calibrated once a day, before it is taken to the field to begin sampling.

Equipment

The following equipment will be needed:

Conductivity meter
Distilled or deionized water
Field record forms.

Procedure

a. Check that the conductivity meter is properly calibrated.
b. Rinse the cup several times with the water to be tested.
c. Fill the cup with the sample.
d. Measure the conductivity.
e. Record the data on the field record form.
f. Discard the sample, refill the sample cup with distilled water, and cap the sample.

C.2.5 pH Measurements

pH measurements are taken during and after purging of the well, just prior to sample collection. Stabilization of pH is used as an indicator to determine if the well bore has been sufficiently evacuated during purging. The pH is considered stable when two consecutive measurements agree within 0.2 pH units. The final pH measurement is taken just prior to sampling and is recorded as an analytical value for the sample. The pH instrument should be calibrated once a day, before it is taken to the field for sampling.

Equipment

The following equipment will be needed:

pH meter
Distilled or deionized water
Field record forms.

Procedure

a. Ensure that the pH instrument is properly calibrated.
b. Rinse the cup with the water to be tested several times.
c. Fill the cup with the sample.
d. Measure the pH of the sample and read to the nearest tenth of a unit.
e. Record the value on the field record form.
f. Discard the sample and refill the cup with distilled water and cap.

C.2.6 Ground-Water Sampling Procedures

All wells must be purged after taking a water level measurement and before sampling. The well should be purged until at least three bore-volumes of water are withdrawn and until pH, temperature, and specific conductivity stabilize. These parameters should be measured at least three times during purging.

Wells may be purged and subsequently sampled using a submersible pump, piezometer bailer, or by air lift as described in the subsections that follow.

General Sampling Precautions

a. Do not smoke, eat, or handle any objects not necessary for sampling while performing sampling procedures.

b. Do not sample downwind of any potential sources of volatile organics such as car exhausts or open fuel tanks. These could contaminate the sample. If such sources are unavoidable, make a note of them on the field record forms.

c. Leave caps on the sample containers until just before filling.

d. Avoid handling the Teflon® bottle cap liners. Do not use any liner that falls out of the cap and onto the ground.

e. Wear gloves when taking samples and when handling containers, especially those with added preservatives.

C.2.6.1 General Sample Collection Procedures

After appropriate sample-line and well purging, ground-water samples should be collected according to the general procedures outlined in this section.

Equipment

The following equipment may be needed:

Rubber gloves
Sample bottles with labels prefixed
Sample seals
Indelible marker
Sample preservatives (depending on the constituents of interest)
Radiation detection instruments
Ice chests with ice
Field record forms
Chain-of-custody forms.

Procedure

a. Fill the sample bottles slowly to avoid splashing or agitating the water, which could trap air bubbles. Also avoid spilling any water on the outside of the bottle, which could contaminate it. For samples requiring no headspace, the bottle should be filled completely so that a meniscus forms.

b. As each container is filled, attach a sample seal to it and place it in an ice chest.

c. Survey the sample container with a Geiger-Müller detector. If the survey indicates greater than 200 cpm, record the reading on the field record form and use applicable Radiation Work Procedures.

d. Complete the chain-of-custody forms.

e. Deliver the sample to the appropriate laboratory for analysis as soon as possible, following chain-of-custody procedures. If the sample cannot be delivered to the lab the same day, store the sample in a refrigerator (or ice chest with ice) located inside a locked building or within a secure area. The refrigerator must maintain a constant temperature of 4°C (39°F).

C.2.6.2 <u>Submersible Pump Sampling Procedures</u>

Submersible pumps are commonly used in taking water samples from wells. However, submersible pumps are not appropriate for sampling all constituents. Some constituents (such as organics) require special equipment so that alterations in the desired sample do not occur (Schmidt 1977). The use of submersible pumps for sampling (as well as all other types of sampling methods) is limited to constituents of interest without these restrictions.

<u>Equipment</u>

The following equipment may be needed:

General sample collection equipment
Bucket (for measuring flow rate)
Gasoline-powered electric generator
Extra discharge line for submersible pump
Stopwatch.

<u>Procedure</u>

a. Take water-level measurements according to the water-level measurement procedure.

b. Check to see that the hose bibb for the submersible pump is open.

c. Caution: Make sure the power switch to the 230-V outlets is turned off!

d. Plug the power cord into one of the 230-V outlets on the generator and into the outlet at the well head.

e. Start the electric generator.

f. Turn the power switch on to begin the pumping process. Be sure not to handle energized power cords. If the pump does not work properly, as indicated by a lack of air flow out the discharge hose or by failure of the generator, [illegible] the switch off immediately. After waiting a few seconds, turn the switch on and off several times rapidly, finally pausing in the ON position to determine if the pump has started properly.

g. After the water begins to flow from the outlet, pump at least 3 bore-volumes and check for stabilization of pH, temperature, and specific conductivity.

h. If the well pumps dry while purging or sampling:

   1. Turn off the submersible pump when the well pumps dry.

   2. Wait for the well to recharge. This should be about 15 minutes, but may be longer.

   3. Measure the depth to water using the E-tape. Make sure that the water level is above the pump intake.

   4. Turn the submersible pump back on.

i. Collect the sample following the general sample collection procedures.

C.2.6.3 Remote-Well Sampling Procedures

Positive displacement pumps are used in remote monitoring wells. The pump may be operated with a pneumatic cylinder or manually.

Equipment

The following equipment may be needed:

General sample collection equipment
Pneumatic cylinder assembly
Hitch pin
Clevis pin
Purging hose
Teflon® sampling hose
Filter assembly
Tubing for the filter adapter 500-mL container
Air compressor
Handle assembly (for manual operation)
Bucket (stainless steel or Teflon®)
Stopwatch.

Procedure

a. Attach the pneumatic cylinder as follows:

   1. Insert the support for the pneumatic cylinder into the column support on the well head assembly. When inserting the cylinder support into the column support on the pump assembly, at least two holes on

the cylinder support must overlap with two holes on the column support. If less than two holes overlap use the extension supplies with the cylinder.

2. Pull the cylinder rod down until it is fully extended and has stopped.

3. Align the eyelet on the top portion of the turnbolt with the clevis pin hole of the lower portion of the cylinder rod.

4. Align the hole on the cylinder support with the column support on the well head so that the turnbolt eyelet and clevis pin hole on the cylinder rod are aligned when the piston is fully extended.

5. Insert the clevis pin through one of the intersecting pairs of holes on the column support and clip a hitch pin into the holes in the small end of the clevis pin.

6. Check the alignment on the turnbolt eyelet with the hole on the cylinder rod. The alignment must be nearly perfect, neither too high nor too low.

7. Adjust by rotating the turnbolt clockwise or counterclockwise.

b. To purge using the pneumatic cylinder:

1. Attach the purging hose (large diameter) to the outlet on the discharge tee of the sampling pump.

2. Attach the quick-connect on the supply hose to the unattached end of the control valve on the pneumatic cylinder. The input air pressure should not exceed 120 psi.

3. Turn air supply on to the control valve.

4. Turn on the control valve on the pneumatic cylinder. The piston will begin to operate.

5. Adjust the stroke rate to no more than 60 per minute. The stroke speed of the pneumatic cylinder can be adjusted with the control valve located on the top of the pneumatic cylinder. At least three bore-volumes should be purged.

6. During purging, periodically collect a sample with the bucket and check for stabilization of pH, temperature, and conductivity and record final values according to procedures.

If the pneumatic cylinder assembly is not operating correctly, and the problems are not due to the well or the pump in the well, the well may be hand pumped as described in the next section.

c. To sample with the pneumatic cylinder:

1. Slow down the pumping rate until the piston operates smoothly. This rate will be less than 10 strokes a minute.

2. Attach the Teflon® sampling hose and purge at this rate for a minimum of two minutes.

3. Proceed with sampling all unfiltered samples according to procedures.

4. To collect filtered samples, turn off air to the pump at the piston assembly. Screw the inlet end of the filter assembly (marked "inlet") into the threaded adapter at the end of the Teflon® tubing, being careful not to touch filter ends to any surface. Slowly turn on the air until the piston operates smoothly. This rate should be less than 10 strokes a minute. If too much pressure is exerted across the filter the membrane will rupture, usually resulting in a popping noise. If this happens, replace the filter and restart the filtering procedure. Filter 500 mL, as a filter wash, into the 500-mL container. Dispose of the 500-mL wash and collect the sample volume needed according to the general sample collection procedure. Turn off the pump, remove the filter assembly, and return the filter assembly to the laboratory for proper disposal.

Manual Procedure

a. Attach the hand pump as follows:

1. Insert the handle support into the column support on the pump head assembly so that at least two holes on the handle support overlap with two holes on the column support.

2. Slide the clevis pin through one of the intersecting pairs of holes on the column support.

3. Clip the hitch pin into the hole in the small end of the clevis pin.

4. Remove the turnbolt on the top of the rod at the well head.

5. Attach the turnbolt on the end of the wire rope attached to the handle assembly onto the threaded rod at the top of the well head.

6. Lift the handle so that the flat edge of the cam nearest the shackle is approximately parallel with the ground.

7. Pull all the slack out of the wire rope.

8. Using either an adjustable or 9/16 open end wrench, tighten both nuts on the shackle until the sheath on the wire rope is compressed.

b. To operate the hand pump:

1. Attach the purging hose (large diameter) to the outlet on the discharge tee of the sampling pump. At least 3 bore-volumes should be pumped. A rate of 20 to 45 strokes per minute seems to work best for purging.

2. During purging, periodically collect a sample with the bucket and check for stabilization of temperature, conductivity, and pH, and record final values according to procedures.

3. To sample, attach the Teflon® sampling hose (small diameter) to the outlet on the discharge tee. A stroke rate of less than 10 strokes per minute should be used.

4. Collect sample according to the general sample collection procedure.

5. To collect filtered samples, follow the procedure outlined in the above section.

C.2.6.4 <u>Piezometer Sampling Procedures</u>

Piezometer tubes can either be sampled by the air lift or bailing methods. The amount of water that the well produces as well as the constituents of interest will dictate which procedure is used. For example, if volatile organics are one of the constituents of interest, then the air lift method would not be appropriate (due to volatile stripping).

<u>Equipment</u>

The following equipment may be needed:

General sample collection equipment
Truck-mounted air compressor and generator
Bucket (Teflon® or stainless steel)
Piezometer bailer

<u>Air Lift Procedure</u>

a. Connect the compressor hose to the piezometer tube.

b. Check the gauge on the compressed air tank. It should read in the operating range prior to the start of air lift. Open the regulator valve to pressurize the hose and continue with the compressor running until water is forced out of the outlet on the side of the piezometer adapter head.

c. Purge the well.

d. Rinse bucket twice before filling for sample.

e. Turn power switch off and then turn off compressor. Unplug power cord.

f. Record sample pH, temperature, and specific conductance according to procedures.

g. Collect sample from bucket following general sample collection procedures.

Bailing Procedure

The bailer generally consists of a flexible Teflon® tube, 1 in. ID and approximately 1-1/2 to 3 ft long. On one end, a stainless steel plug is inserted and wired in place.

a. Bail the piezometer tube in the same manner as the well casings are bailed.

b. After pumping, record the sample pH, temperature, and specific conductance according to procedures.

c. Collect the sample following general sample collection procedures.

C.2.7 Equipment Cleaning Procedures

All equipment that comes into contact with the samples and is reused should be properly cleaned to avoid cross-contamination between wells. The following procedure should be used:

a. Wash the inside and outside of the item with a mild mixture of dish soap and water.

b. Rinse the item twice with tap water.

c. Store the item in a sealable plastic bag or other appropriate container between uses.

C.2.8 Chain-of-Custody Procedures

To ensure the integrity of the samples from the time of collection through analysis and data reporting, the history of the custody of each sample should be documented according to specific procedures. A sample is considered to be under a person's custody if it is in any of the following states: (1) in his personal possession, (2) in his view after he has taken possession, (3) secured by him so that no one can tamper with the sample, or (4) secured by him in an area that is restricted to authorized personnel. Anyone having custody of samples must comply with the procedures described below.

C.2.8.1 Delivery Procedures

Sample Labels. Fill out and affix the gummed paper labels to the sample containers prior to the time of sample collection. The well number noted on the label identifies the well location where the sample was collected.

Sample Seals. Attach gummed paper seals to the samples immediately upon sample collection, before the samples leave your custody. Attach them in such a way that the sample cannot be opened without breaking the seal.

Field Record Form. Record (in black ink) all pertinent information about each sample collected on a field record-form and insert into a binder. It will be a bound book with consecutively numbered pages.

Chain-of-Custody Form. A chain-of-custody form will accompany all samples from the time they are collected until they are disposed of after analysis and reporting. A single form will be used for as many samples as possible. Each person who handles the sample and signs the form will return a copy of the form to the company contact whose name appears on the top line. Samples should be delivered directly to the laboratory on the day of collection. If they cannot be delivered on the day of collection, they must be stored in a refrigerator or packed in ice in a locked building. All samples will be accompanied by a chain-of-custody form. Deliver samples only to authorized laboratory personnel.

C.2.8.2 Laboratory Acceptance Procedures

The chain-of-custody does not end at the laboratory door. Therefore, the laboratory must ensure the continuity of its record by following the proper procedures.

The LABORATORY RECEIVING DEPARTMENT should:

a. Remove the sample cooler(s) from the delivery vehicle and bring it into the receiving area.

b. Check the sample cooler(s) for any obvious damage.

c. Sign the chain-of-custody form.

d. If you transfer custody of the cooler(s) to one or more intermediates before it is delivered to the Sample Custodian, the chain-of-custody form must reflect every change of custody.

The LABORATORY SAMPLE CUSTODIAN should:

a. Sign the chain-of-custody form upon delivery of the sample cooler(s). One copy should be returned to the sender. The other copies should be kept.

b. Log in the samples:

   1. Note the presence/absence and condition of the custody seals on the samples.

   2. Record whether chain-of-custody forms are present and completed properly.

3. Remove the sample containers from the cooler(s) and note the condition of the samples, the presence/absence of sample labels and sample seals, and any discrepancy with the chain-of-custody form(s).

c. If discrepancies are found, contact the sender for clarification.

d. Once all samples have been properly logged in, send a copy of the sample log-in form to the company contact named on the chain-of-custody form.

e. Use an internal numbering system for the identification of all samples.

f. Assign internal numbers to the samples and record the numbers on the sample log-in form alongside the corresponding sample number assigned by the collector.

g. Place the properly labeled sample containers in the secure storage area.

C.3 QUALITY CONTROL AND STATISTICAL ANALYSIS

There has been a propensity over the years to collect data when and where one wanted to have information (Nelson and Ward 1981; Loftis and Ward 1979). A change has occurred in data analysis to characterize the value of some parameter in a portion of the environment from which it was collected and determine some state of accuracy with a limited number of data points. As a result, some general principles can be applied to the water monitoring described in this appendix.

1) One datum point will provide only an estimate of the parameter value and in most cases has a very large uncertainty associated with it. Standing alone, this datum is of little value.

2) Spatial and temporal variations may or may not have significance (EPA 1980). Although spatial variation is not important when doing trend analysis, temporal variation is important. For inventory use, temporal variation is not important but spatial distribution is critical. If a dose from a radiological source is the issue, both temporal and spatial distribution are critical.

3) Systematic sampling is necessary for the determination of temporal variations and spatial distribution. Random sampling will be of little value.

4) The accuracy and validity of the data must be evaluated before any action is taken, based on incoming information. It can be expected that there will be random (precision) and systematic (bias) errors in the data.

Some sources of variability in data are: 1) distance from a source, elevation, and non-uniform dispersion; 2) variations in the source emission and dispersion parameters; 3) nonrepresentative sampling of heterogeneous media, non-uniform sampling techniques, and sampler failures; 4) reaction with the sample containers; 5) volumetric errors, the collection of nonhomogeneous samples, and not following uniform processes in the collection of samples; and 6) instrument errors, which consist of calibration, counting variability, calculation, and readout errors.

Various statistical tools are available for the determination of the accuracy and validity of data as identified in this document. A brief listing of the possible items that should be explored when determining the validity and accuracy of a system for surface- and ground-water monitoring is provided below:

- Sources of variability
- Estimates of the accuracy or bias of results
- Estimates of precision of the results
- Testing for the homogeneity of a sample
- Determining central values and data dispersion
- Handling "less than detectable" values
- Comparing various sets of data.

By applying the above listed parameters to the location of sampling sites, the sampling methods, the sample collection, the analysis of the sample, and the interpretation of the data, a monitoring program for surface water and ground water can be expected to produce data that will be representative of the environment from which it was collected. These data will assist in the operation of a facility and help in the protection of the environment.

C.4 REFERENCES

American Public Health Association (APHA), American Water Works Association, and Water Pollution Control Federation. 1980. Standard Methods for the Examination of Water and Wastewater, 15th edition. American Public Health Association, Washington, D.C.

American Society for Testing and Materials (ASTM). 1979. "Water." In Annual Book of Standards. Part 31, American Society for Testing and Materials, Philadelphia.

Brown, E., M. W. Skougstad, and M. J. Fishman. 1970. Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases. Stock No. 2401-1015, U.S. Government Printing Office, Washington, D.C.

Casey, D., P. N. Nemetz, and D. H. Uyeno. 1983. "Sampling Frequency for Water Quality Monitoring: Measures of Effectiveness." Water Resources Research 19(5):1107-1110.

Cherry, J. A. 1983. "Migration of Contaminants in Groundwater at a Landfill: A Case Study." Journal of Hydrology 63(1/2)(Special Issue).

Cherry, J. A., and P. E. Johnson. 1982. "A Multilevel Device for Monitoring in Fractured Rock." Ground Water Monitoring Review, Summer, 41-44.

Diefendorf, A. F., and R. Ausburn. 1977. "Groundwater Monitoring Wells." Public Works 108(7):48-50.

Executive Order 12088. 1978. "Federal Compliance with Pollution Control Standards."

Federal Water Pollution Control Act Amendments of 1972. Pub. Law 92-500, 33 U.S.C. 466 et seq.

Gibb, J. P., R. M. Schuller, and R. A. Griffin. 1981. "Procedures for the Collection of Representative Water Quality Data from Monitoring Wells." Cooperative Groundwater Report 7, Illinois State Water Survey, Illinois State Geological Survey, Urbana, Illinois.

Jackson, R. E., and R. J. Patterson. 1982. "Interpretation of pH and Eh Trends in a Fluvial-Sand Aquifer System." Water Resources Research 18(4):1255-1268.

Jaffee, P. R., F. L. Parker, and D. J. Wilson. 1982. "Distribution of Toxic Substances in Rivers." Journal of Environmental Engineering Division, Proceedings of the American Society of Civil Engineers 108(EE4):639-649.

Johnson Division, UOP, Inc. 1980. Groundwater and Wells. UOP, Inc., St. Paul, Minnesota.

Kennedy, V. C., G. W. Zellweger, and B. F. Jones. 1974. "Filter Pore Size Effects on the Analysis of Al, Fe, Mn, and Ti in Water." Water Resources Research 10(4):785-790.

Korte, N., and D. Ealey. 1983. Procedures for Field Chemical Analyses of Water Samples. Technical Measurements Center Report GJ/TMC-07(83), Bendix Field Engineering Corporation, Grand Junction, Colorado.

Korte, N., and P. Kearl. 1984. Procedures for the Collection and Preservation of Groundwater and Surface Water Samples and for the Installation of Monitoring Wells. Technical Measurements Center Report GJ/TMC-08, Bendix Field Engineering Corporation, Grand Junction, Colorado.

Kruseman, G. P., and N. A. DeRidder. 1979. Analysis and Evaluation of Pumping Test Data. ISBN No. 90-70260-360, International Institute for Land Reclamation and Improvement, The Netherlands.

Langmuir, D. 1971. "Eh-pH Determinations." In Procedures in Sedimentary Petrology, R. E. Carver, ed. Wiley and Son, Inc., New York, New York.

LeGrand, H. E. 1968. "Monitoring of Changes in Quality of Groundwater." Groundwater 6(3):14-18.

Loftis, J. C., and R. C. Ward. 1979. Regulatory Water Quality Monitoring Networks--Statistical and Economic Considerations. EPA 600/4-79-055, U.S. Environmental Protection Agency, Washington, D.C.

Nelson, J. D., and R. C. Ward. 1981. "Statistical Considerations and Sampling Techniques for Ground-Water Quality Monitoring." Groundwater 19(6).

Parizek, R. R., and B. E. Lane. 1970. "Soil-Water Sampling Using Pan and Deep Pressure-Vacuum Lysimeters." Journal of Hydrology 11:1-21.

Pickens, J. F., and G. E. Grisak. 1979. "Reply to Discussion by J. A. Vanhof et al. of 'A Multilevel Device for Ground-Water Sampling and Piezometric Monitoring.'" Ground Water 17 (4):393-397.

Pickens, J. F., J. A. Cherry, R. M. Coupland, G. E. Grisak, W. F. Merritt, and B. A. Risto. 1981. "A Multilevel Device for Ground-Water Sampling." Ground Water Monitoring Review, Spring, pp. 48-51.

Resource Conservation and Recovery Act (RCRA); Public Law 94-580, as amended, 42 U.S.C. 6901 et seq.

Rich, C. A. 1980. "Hydrogeologic Considerations in Waste Management--A New Frontier." Engineering Bulletin, Vol. 55, March, pp. 5-18.

Safe Drinking Water Act of 1974; Public Law 93-523, 42 U.S.C. 300f et seq.

Scalf, M. R., F. McNabb, J. D. William, R. L. Costy, and J. Fryberger. 1981. Manual of Ground-Water Quality Sampling Procedures. EPA-600/2-81-160, U.S. Environmental Protection Agency, Ada, Oklahoma.

Schmidt, K. D. 1977. "Water Quality Variations for Pumping Wells." Groundwater 15(2):130-137.

Todd, D. K., R. M. Tinlin, K. D. Schmidt, and L. G. Everett. 1976. Monitoring Groundwater Quality: Monitoring Methodology. EPA 600/4-76-026, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Army Toxic and Hazardous Materials Agency (USATHMA). 1982. Minimum Requirements for Boring Logs, Drilling Procedures, Monitoring Well Installation and Associated Data Management System Entries. Aberdeen Proving Ground, Aberdeen, Maryland.

U.S. Environmental Protection Agency (EPA). 1975. Manual of Water Well Construction Practices. EPA-570/9-75-0012, Office of Water Support, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1979a. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1979b. Handbook for Analytical Quality Control in Water and Wastewater Laboratories. EPA-600/4-79-019, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1980. Prescribed Procedures for Measurement of Radioactivity in Drinking Water. EPA-600/4-80-032, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Geological Survey (USGS). 1977. National Handbook of Recommended Methods for Water Data Acquisition. U.S. Department of the Interior, Washington, D.C.

U.S. Government Accounting Office (GAO). 1981. Better Monitoring Techniques Are Needed to Assess the Quality of Rivers and Streams. Vol. I and II, CED-81-30, U.S. Government Accounting Office, Washington, D.C.

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Licensing of a facility for low-level radioactive waste disposal requires the review of the environmental monitoring and surveillance programs. A set of review criteria is recommended for the U.S. Nuclear Regulatory Commission (NRC) staff to use in each monitoring phase-- preoperational, operational, and postoperational-- for evaluating radiological and selected nonradiological parameters in proposed environmental monitoring and surveillance programs at low-level waste disposal facilities. Applicable regulations, industry standards, and technical guidance on low-level radioactive waste are noted throughout the document. In the preoperational phase, the applicant must demonstrate that the environmental monitoring program identifies radiation levels and radionuclide concentrations at the site and also provides adequate basic data on the disposal site. In the operational phase, the applicant must demonstrate that considerable care has been taken in designing and implementing the environmental monitoring programs and that data obtained during the first phase are reflected in the design of those programs. The operational phase must also be technically sound and broad enough to address potential issues that may be raised by the public. The postoperational phase requires continued sampling and measurements of those media that may provide a future exposure pathway to the public, perhaps at a reduced frequency during the long-term care period, based on the data obtained during the operational phase. Review checklists are provided for NRC use in evaluating the adequacy of environmental monitoring and surveillance programs for compliance with applicable regulations.

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