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Emergency Environmental Sampling and Analysis for Radioactive Material Facilities

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ABSTRACT

This report provides information that could be used by radioactive material facilities for developing or improving environmental sampling and analysis programs for emergency conditions. Areas that need to be addressed during the planning phase of such a program include 1) emergency organization, 2) sample collection and measurement locations, 3) required equipment and supplies, 4) sample collection procedures, 5) field measurement methods, 6) recordkeeping methods, and 7) quality assurance program. Emphasis is placed on the need for these facilities to coordinate monitoring activities with any supporting agencies, such as state and federal monitoring teams who might respond. The report also reviews the responsibilities and current capabilities of radioactive material facilities, state and local government agencies, and federal agencies with regard to environmental sampling and analysis in an emergency situation.

SUMMARY

Past accidents have identified the need for facilities and offsite agencies performing environmental sampling and analysis to coordinate sample collection and analysis activities. In response to this need, the U.S. Nuclear Regulatory Commission (NRC) contracted with the Pacific Northwest Laboratory (PNL) to develop environmental sampling and analysis information for licensees as it relates to emergency situations at U.S. nuclear fuel cycle and other radioactive material facilities.

The major topics discussed in the report include lessons learned from a prior UF_6 cylinder rupture accident; the responsibilities and current capabilities of radioactive material facilities, state, and federal agencies; and the major components of an emergency environmental sampling and analysis program. Information presented in this report was obtained from a review of pertinent documentation and from interviews with personnel at selected facilities, state agencies, and U.S. Department of Energy (DOE) regional offices and contractors.

Lessons learned from a prior UF_6 cylinder rupture accident included the needs for 1) procedures addressing the organization, dispatching, and controlling of field teams, 2) adequate maps depicting major and secondary roads, topography, and population centers near the facility, 3) emergency monitoring equipment to be located in areas not likely to be affected by the accident, 4) standardized environmental sampling and analysis procedures, and 5) intercomparison of laboratory results if multiple organizations are involved in environmental monitoring.

In planning and developing an emergency environmental sampling and analysis program, facilities need to consider the following: emergency organization, sample collection and measurement locations, types of emergency equipment and supplies, sample collection procedures, coordination with offsite agencies, recordkeeping, and quality assurance (QA) programs. Their emergency organization should consist of several field teams and supervisory personnel to control the teams. Procedures need to be developed addressing assembly, preparation, and dispatch of field teams, contamination control, and personnel exposure control. A method for rapidly locating sample collection points, such as a radial grid system, needs to be included in field team procedures.

Equipment and supplies that should be part of an emergency environmental sampling and analysis program include appropriate radiation detection instruments for performing measurements in the field and in the laboratory. Portable survey instruments (i.e., Geiger-Mueller (GM) detectors, ion chambers, μR meters) should be available for the initial field measurements. Initial field measurements performed by field teams should be geared toward defining the boundaries of the contamination so that access to the affected area can be restricted. Laboratory analysis of samples would include both rapid and detailed analyses. Rapid types of analyses would include gross alpha and beta counting and gamma spectrometer analyses with minimum sample preparation. These would be done immediately following the accident when results are needed

quickly. More detailed analyses involving elaborate sample preparation or radiochemical separation procedures would be appropriate after affected areas have been identified. Other equipment and supplies should include air sampling equipment, sample collection supplies, personnel protection supplies, and field team vehicles.

Facilities need to consider problems of coordinating with state or federal support groups in an emergency. It would be extremely beneficial to be aware of the capabilities and procedures used by the state and federal agencies that could provide environmental monitoring assistance in an emergency. Facility procedures should also address the need for an initial and periodic meetings among all agencies performing sampling and analysis in an emergency to coordinate sample collection and analysis.

Methods should be developed for sampling soil, vegetation, water, snow, milk, and air. Sample collection methods should address preferred locations for sampling, contamination control practices, sampling equipment, and sample bagging, labeling, and transport. Good recordkeeping is an essential part of emergency sampling activities. Field teams need to clearly label all samples including information such as the team collecting the sample, sample location, sample time, sample type, sample size or area, and radiation level of the sample as measured using a portable survey instrument.

A QA program should be provided for the emergency environmental sampling and analysis program. A QA program ensures that emergency equipment and supplies are inventoried and maintained and that laboratory analyses are performed in an acceptable manner. The components of a good program for analytical measurements should include background counts, source checks, calibration of all counters, periodic analysis of quality control samples, and an interlaboratory comparison with any other organizations performing analyses during the emergency.

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1.0 INTRODUCTION

After an accident involving radioactive material, data obtained from a facility's emergency environmental sampling and analysis program would provide information on the release and extent of contamination. An early qualitative assessment of the accident in the first few hours is necessary, to be followed in the days, weeks, and months afterward by a quantitative assessment. Past accidents have identified the need for a facility and offsite agencies performing environmental sampling and analysis to coordinate sample collection and analysis activities. In response to this need, the U.S. Nuclear Regulatory Commission (NRC) contracted with the Pacific Northwest Laboratory (PNL) to develop emergency environmental sampling and analysis information for U.S. fuel cycle and other radioactive material facilities, referred to as radioactive material facilities in this report. These facilities include nuclear fuel fabrication facilities, UF_6 production facilities, radiopharmaceutical manufacturers, sealed-source manufacturers, and nuclear fuel research and development facilities. This information can also assist the radioactive material facilities in developing or making improvements to their emergency programs for environmental sampling and analysis, that may be required as a result of the Proposed Rule on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees 1987 (Fed. Reg. 1987).

Accidents at fuel cycle and other radioactive material facilities would typically result in radiological releases of short duration that would probably not allow enough time for field teams to perform plume tracking or obtain air samples from the plume. Information obtained from the emergency environmental sampling and analysis program would be derived from the radioactive material deposited on the ground. This represents a major difference between programs at radioactive material facilities and those at nuclear power plants. Accidents at nuclear power plants are more likely to result in radiological releases that would be of a longer duration. In addition, releases would be anticipated based on deteriorating plant conditions. Such situations would allow sufficient time for dispatching field teams to track the plume.

This report provides environmental sampling and analysis information that should be useful to radioactive material facilities in planning for an emergency. The information addressed includes how emergency environmental data should be used, the emergency organization required, how to define sample collection and measurement locations, equipment and supplies needed for sampling and analysis, sample collection procedures, good practices in performing field measurements, how to coordinate with offsite agencies, recordkeeping procedures, and a quality assurance program. Also included in the report is a discussion of lessons learned in emergency environmental sampling and analysis at a previous UF_6 cylinder rupture accident, as well as responsibilities and current capabilities of facilities, states, and the U.S. Department of Energy (DOE) with regard to emergency environmental sampling and analysis.

Information for this report was obtained from pertinent documents on environmental sampling and analysis and discussions with personnel from selected radioactive material facilities, state agencies responsible for environmental monitoring, and DOE regional offices and contractors. Emergency plans and procedures from selected facilities, state agencies, DOE Radiological Assistance Regions, and DOE contractors were also reviewed.

2.0 LESSONS LEARNED FROM A UF_6 CYLINDER RUPTURE ACCIDENT

A 14-ton uranium hexafluoride (UF_6) cylinder ruptured at the Sequoyah Fuels Corporation (SFC) site on January 4, 1986 resulting in the release of approximately 14,750 lb (6700 kg) of UF_6 to the environment (NRC 1986a). The UF_6 released into the environment reacted with the moisture in the atmosphere to form uranyl fluoride (UO_2F_2) and hydrofluoric acid (HF). Approximately 12,900 lb (5900 kg) of UO_2F_2 and approximately 3350 lb (1500 kg) HF were formed when the UF_6 was released (NRC 1986a). The remaining contents from the cylinder were washed to the facility's emergency basin for containment.

Organizations responding to the accident included the Sequoyah Fuels Corporation (SFC), Kerr-McGee Corporation, Oklahoma State Department of Health (OSDH), EG&G Las Vegas, Oak Ridge National Laboratory (ORNL), and the NRC. After the accident, SFC performed environmental sampling. The samples collected were sent to the Kerr-McGee Corporation Technical Center for analysis. The OSDH also performed environmental sampling and analysis. After being called in by the NRC, ORNL performed sample analysis along with OSDH and the Kerr-McGee Corporation Technical Center. EG&G Las Vegas performed aerial surveys and in situ readings, and maintained the data base of environmental sample results.

The following lessons were learned from emergency environmental sampling and analysis of the Sequoyah UF_6 cylinder rupture accident:

- Facilities need procedures for organizing, dispatching, and controlling their field teams in an emergency. The routine environmental sampling procedures used by SFC during the accident were limited to collection of environmental samples and contained no guidance on dispatching or controlling field teams.

- Facilities need adequate maps for use by field teams and staff controlling the teams. Some map development was done immediately following the Sequoyah accident to provide field teams with adequate maps for locating sampling points.

- Emergency personnel need to be trained in the Radiological Contingency Plan including emergency sample collection and analysis methods (NRC 1986b). Such training would help ensure that environmental samples are collected and analyzed in a consistent manner.

- Emergency kits used for onsite and offsite monitoring need to be located in areas that are not likely to be affected by an accident, or multiple equipment storage locations need to be provided (NRC 1986b). Equipment could be contaminated by the released material, or access to the kits could be impaired. At the Sequoyah accident, access to much of the equipment was initially prevented by the cloud of HF and UO_2F_2.

- Standardized sampling and analysis procedures need to be established early in an accident if multiple organizations are involved (NRC 1986b). Differing sampling and analytical methods were used by OSDH and SFC during the first several days after the accident which produced sample results that could not be compared. For example, a problem arose when comparing fluoride analysis results for soil samples. Both the facility and OSDH used routine environmental sample collection procedures and routine analytical procedures because personnel were familiar with these procedures. The SFC measurements were approximately two times greater than OSDH sample measurements. A later review revealed that SFC performed a total assay for fluorides while OSDH did an analysis of the soluble portion only. This resulted in confusion during analysis of the accident effects and could have been avoided if sampling and analysis procedures had been firmly established and understood during an initial coordination meeting between the facility and OSDH.

- A means for intercomparing laboratory results also needs to be established early in an accident if multiple organizations are involved (NRC 1986b). Some environmental samples need to be split and analyzed by all responding organizations to establish whether all the analytical methods are providing comparable results. The NRC initiated such a program several days into the Sequoyah accident.

3.0 RESPONSIBILITIES AND CAPABILITIES OF FACILITIES AND GOVERNMENT AGENCIES

The responsibilities of facilities, states, DOE and their contractors, NRC, and the Environmental Protection Agency (EPA) regarding emergency environmental sampling and analysis are presented in this section. Facilities have the responsibility for emergency environmental monitoring onsite (within their site boundaries). The facilities must also do environmental monitoring to meet reporting requirements in 10 CFR 20 (CFR 1988) Part 20.403 (Notifications of Incidents) and Part 20.405 (Reports of Overexposures and Excessive Levels and Concentrations). State and local agencies have the responsibility for protecting public health and safety, which is likely to require emergency environmental monitoring offsite. DOE and its contractors are responsible for providing offsite monitoring support to state agencies during the initial and intermediate phases of an emergency, if requested. At fuel cycle and other radioactive material facilities, NRC has jurisdiction over the radioactive material causing the emergency and has the authority to take action onsite, as required in the Federal Radiological Emergency Response Plan (Fed. Reg. 1985). The EPA is responsible for providing offsite monitoring support to state agencies, if requested, during the recovery phase of the emergency.

A discussion of current emergency environmental sampling and analysis capabilities is included to give radioactive material facilities an indication of how their capabilities compare to those of other facilities and to provide guidance on the type of support available from state and federal agencies. Finally, a discussion is provided on how facility, state, and federal agencies may interface with regard to emergency environmental sampling and analysis during an emergency.

3.1 FACILITIES

In February 1981, the NRC issued orders requiring 62 licensees to submit comprehensive onsite radiological contingency plans. The licensees were to upgrade emergency preparedness and address issues identified by analyses of the Three Mile Island accident. These radiological contingency plans were based on the guidance in NUREG-0762 (NRC 1981). This guidance specifies that the licensees should identify in their radiological contingency plans all equipment that would be used in emergency monitoring. About half of the 62 licensees submitted plans; the other licensees reduced their authorized possession limits so that they were no longer required to submit plans. Those submitting plans included fuel fabrication facilities, UF_6 production facilities, fuel research and development facilities, sealed-source manufacturers, and radiopharmaceutical manufacturers.

The NRC issued a Proposed Rule on Emergency Preparedness for Fuel Cycle and Other Radioactive Material Licensees (Fed. Reg. 1987). If the new rule is promulgated, approximately 30 licensees will be required to revise their existing radiological contingency plans (emergency plans) if accidental releases from "a credible severe accident could theoretically deliver a radiation dose of 1 rem effective dose equivalent, 5 rem to the thyroid, or soluble uranium intake exceeding 2 milligrams to a member of the public." The emergency plans will be required to provide descriptions of the means and equipment for mitigating the consequences of an accident and for promptly notifying offsite response organizations in the event of a significant release of radioactive materials. For each potential credible accident that could result in significant offsite releases, the licensee is to include in the plan recommendations that would be made to offsite response organizations for each accident type. This will include predetermined protective action recommendations (PARs) for the offsite agencies. Appendix A includes a discussion of federal guidance on protective action guides for airborne radioactive materials, human and animal feeds, and other media. A discussion on developing protective action recommendations is found is NUREG-1140 (NRC 1985).

3.1.1 Capabilities

Reviews were performed of the emergency environmental sampling and analysis programs of 12 facilities. Five of the facilities surveyed had emergency environmental sampling procedures for use in accident situations; four facilities indicated they would rely on their routine environmental sampling procedures; and three facilities did not have any environmental sampling procedures for use during an accident. The five facilities with emergency environmental procedures provided information on assembling, dispatching, and controlling environmental monitoring teams during an emergency in their procedures. These facilities would rely on routine procedures for the collection and analysis of environmental samples during an accident.

3.1.2 Interface with Other Agencies

When a facility has an accident that requires notifying offsite agencies, state and local governments should be notified first followed by the NRC and any other agencies (e.g., DOE) or groups (e.g., vendors) that may be able to provide needed services. The facility can request environmental sampling and analysis support directly from DOE if they feel an immediate need, although normally the state would contact DOE.

3.2 STATE AND LOCAL GOVERNMENTS

State and/or local governments have the overall responsibility for protecting the health and safety of the general public from radiological releases. In support of this responsibility, state or local governments can provide offsite field teams to collect and analyze environmental samples in the affected area. Generally, state governments provide the offsite monitoring capability as discussed in the following section.

3.2.1 Capabilities

A review of the emergency environmental sampling and analysis programs for seven state agencies was performed. Each state had at least one radioactive material facility. All seven states had emergency environmental sample collection procedures, and all but one of the states had a laboratory and procedures for preparing and analyzing the samples.

A review of emergency environmental sampling and analysis procedures for these states indicated that guidance was provided in six main areas - sample collection, external exposure rate measurements, field team dispatch, field analysis of samples, laboratory analysis of samples, and quality control (QC) measures in the laboratory. Sample collection methods were described for air, soil, vegetation, ground water, drinking water, surface water, milk, sediment, and snow samples. Methods for taking external exposure rate measurements to determine location of the plume or the extent of ground deposition were described in the procedures. Regarding field team dispatch, the procedures included discussions on field team composition, equipment and supplies, operability checks on instruments, and field team briefings. Guidance on using portable survey instruments to obtain a preliminary estimate of field sample activities was provided as well as guidance on laboratory analysis of samples, including sample preparation methods, radiochemical separation methods, and counting methods. Some procedures also included a discussion of QC methods to be used in the analytical laboratory.

3.2.2 Interface with Other Agencies

The state would receive notification from the facility in the event of an emergency. The facility should provide the state with the following information: facility status, whether the accident involved an offsite radioactive release, and any recommended protective actions. Based on this information, the state would dispatch offsite field teams to the site if necessary. When assessing the situation, the state would have the option of calling in federal support agencies if deemed necessary. For offsite radiological assessment, assistance could be requested from DOE as part of the Radiological Assistance Program (RAP) or the Federal Radiological Monitoring and Assessment Plan (FRMAP).

3.3 U.S. DEPARTMENT OF ENERGY

The DOE and its contractors have the responsibility for providing offsite monitoring support to state and local agencies and to facilities, if requested, during an emergency (Fed. Reg. 1985). Depending on the severity of the emergency, DOE can provide a graded response which could range from providing technical assistance to the state over the phone to dispatching numerous DOE or DOE contractor teams to the site. In the event of a major emergency, DOE can request support of other federal agencies through the Federal Radiological Emergency Response Plan of 1985 (Fed. Reg. 1985). The remainder of this section describes the Federal Plan and DOE's responsibilities within it.

The Federal Plan establishes guidelines for providing federal support to state and local governments beyond the facility boundary in the event of peacetime radiological emergency (e.g., accident at a nuclear facility or a transportation accident). As part of the Federal Plan, DOE developed the Federal Radiological Monitoring and Assessment Plan (FRMAP) under 44 CFR

351 (CFR 1985). There are four major purposes of FRMAP. First, to make radiological monitoring and assessment assistance available to state and local governments and to facilities in emergency situations. Second, to establish a framework through which federal agencies will coordinate any radiological monitoring and assessment assistance provided to state/local governments or facilities. Third, to maintain a liaison and a common set of offsite radiological monitoring data with the licensee, state, and the cognizant federal agency.[a] Finally, under FRMAP, DOE will assist state and local governments in preparing for radiological emergencies by describing federal agencies' responsibilities.

Depending on the severity of an emergency, FRMAP has the flexibility of offering a graded response. For example, in many situations, limited response by several members of a DOE Radiological Assistance Program (RAP) team would be adequate assistance. Each of the eight DOE Radiological Assistance Regions (Table 3.1) has RAP teams (usually composed of DOE and DOE contractor personnel) to respond to minor emergencies or to major emergencies until additional support can be obtained through FRMAP. This additional support could be in the form of additional DOE or DOE contractor personnel or a full implementation of FRMAP involving other federal agencies such as NRC, EPA, Department of Health and Human Services, Department of Agriculture, Department of Commerce, Department of Transportation, Department of Defense, Department of Interior, National Communications Systems, Department of Housing and Urban Development, and Federal Emergency Management Agency. In the case of a severe accident with full FRMAP implementation, offsite radiological monitoring and assessment activities would be operated out of a center near the scene of the accident. This center is called the Federal Radiological Monitoring and Assessment Center (FRMAC) and is located outside the area affected by the accident. Doyle (1987) provides additional information on the FRMAC.

Each of the DOE Radiological Assistance Regions has been required to write a FRMAP specific to their region. A typical plan includes a list of all the federal agencies involved and their responsibilities, discussion on how the plan is activated, and a description of the organizational structure of FRMAC. The plan also includes a list of personnel by title who will man the FRMAC and their responsibilities.

3.3.1 Capabilities

The current emergency environmental sampling and monitoring capabilities of the seven DOE Radiological Assistance Regions with radioactive material facilities are reviewed in this section. Four of the regions have formalized FRMAPs, two had draft FRMAPs, and one region had no FRMAP. The FRMAPs define DOE and DOE contractor elements that would respond to an accident and provide support in emergency environmental sampling and analysis. The DOE contractors can respond as part of a RAP response or FRMAP response, depending on the severity of the accident. The number of contractors who can supply RAP teams

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(a) The cognizant federal agency would be the NRC in the event of an emergency at a radioactive material facility.

TABLE 3.1. DOE Radiological Assistance Regions

Radiological Assistance Region	States in Each Region
Region 1 - Brookhaven[a]	ME, NH, VT, NY, MA, CN, RI, PA, NJ, MD, DE, DC
Region 2 - Oak Ridge[a]	MO, AR, LA, MS, TN, KY, WV, VA
Region 3 - Savannah River[a]	AL, GA, FL, SC, NC
Region 4 - Albuquerque[a]	AZ, NM, TX, OK, KS
Region 5 - Chicago[a]	ND, SD, NE, MN, IA, WI, IL, IN, OH, MI
Region 6 - Idaho Falls	ID, MT, WY, UT, CO
Region 7 - San Francisco[a]	CA, NV, HI
Region 8 - Richland[a]	OR, WA, AK

(a) Contacted to obtain information on their Federal Radiological Monitoring Assessment Plans and Procedures.

varies among the regions dependent on the number of nuclear facilities located within the region. Each region has a lead contractor with additional environmental sampling and analysis capabilities such as a mobile laboratory.

Radiological Assistance Region program managers know the capabilities of the contractors who support their FRMAP. For example, they know manpower resources, portable radiation survey instrument capabilities, analytical capabilities, air sampling capabilities, and environmental media sampling capabilities for each of the contractors. However, the regions generally have not developed associated FRMAP implementing procedures describing environmental sample collection techniques and sample analysis methods. In most cases, the DOE contractors will rely on their own procedures for environmental sample collection and analysis.

A review of nine DOE contractors designated to provide radiological monitoring assistance through RAP or FRMAP revealed that only two of the nine contractors had emergency sample collection procedures; the others relied on collection procedures that were part of their routine environmental surveillance program or the applicable state sample collection procedures. DOE support personnel from Radiological Assistance Regions 2 and 5 would use state collection procedures, if available, because DOE would be in a position to support the state response during an emergency. All nine contractors would rely on analytical procedures that were part of their routine environmental surveillance program.

The emergency environmental sampling procedures currently in use by two DOE contractors include procedures for:

- external exposure rate measurements performed in the field
- collection of environmental media (air, soil, surface water, milk, vegetation, snow, rain, and crops)
- measurement methods in a mobile environmental laboratory (e.g., use of gas flow proportional counter, NaI detector, and portable multichannel analyzer)
- radio communications
- field estimates of radionuclide concentrations in vegetation, water, and air samples based on portable survey instrument measurements and portable gamma spectrometer measurements
- special monitoring methods (e.g., aerial surveys, road monitors)
- grid surveys of potentially contaminated areas.

In addition to the DOE support that can be provided by means of regional contractors, a nationwide DOE support capability is available through EG&G Las Vegas. Nationally, EG&G provides assistance by performing aerial surveys, in situ gamma spectroscopy measurements, and in establishing a data base for recording all environmental measurements and environmental sample analyses. EG&G is also capable of providing communications equipment, logistical and administrative support (in the form of equipment and personnel), and technical staff for the FRMAC.

3.3.2 Interface with Other Agencies

One of DOE's responsibilities under FRMAP is to assist state and local governments in preparing for a radiological emergency. This includes providing guidance on the type of information state and local governments or facilities should report to DOE when requesting their assistance. This information should include:

- name, title, location, and phone number of person reporting the accident
- brief description of the accident including location, date and time it occurred, nature of the accident, any offsite releases, and prognosis of the emergency
- list of radionuclides involved, their physical and chemical form, and approximate quantities

- meteorological conditions, such as wind direction and wind speed

- for a transportation accident, description of shipping container, information on the shipper (name, address, and phone number), whether material was escorted, radiation readings around container, type of instrument used to read radiation levels

- for a fixed nuclear facility, extent of offsite releases and how measured, whether dose projections have been made (if facility has the capability)

- extent of damage and personal injury

- protective actions taken onsite and offsite

- information released to the public regarding the accident.

The state or facility should be able to provide these general types of information when requesting DOE assistance. This information will help the DOE teams determine the extent of response necessary and types of equipment to bring to an accident site.

An initial call for assistance will go to the appropriate DOE Radiological Assistance Region. Based on information received from the caller, the Region will determine the level of response that is appropriate. This could range from providing advice over the phone to an agency-wide FRMAP response with the establishment of a FRMAC. DOE Headquarters must approve an agency-wide FRMAP response. If this is established, DOE must coordinate with EPA at the FRMAC to determine when responsibility for offsite radiological monitoring and assessment should be turned over to the EPA. This would normally occur before the long-term recovery phase begins.

3.4 OTHER GOVERNMENT AGENCIES

The cognizant federal agency (CFA) is the federal agency that owns, authorizes, regulates, or otherwise has jurisdiction over the radiological activity causing the emergency and that has the authority to take action onsite (Fed. Reg. 1985). The NRC is the CFA for most radioactive material facilities. In agreement states, a state licensing agency may have the same responsibilities as the CFA. With regard to offsite monitoring, NRC has the responsibility to provide DOE or the state (if FRMAP has not been implemented) with offsite monitoring data collected by the licensee or themselves and to update DOE or the state concerning onsite conditions that may affect offsite monitoring efforts.

Each of the five NRC regions has an environmental mobile laboratory capable of responding to accident sites within the region. The mobile labs are typically equipped with a gas flow proportional counter, Ge(Li) gamma spectroscopy system, NaI detection system, several portable survey instruments, and high and low volume air samplers. The NRC does not collect any samples but can analyze samples collected by other groups. In many cases, the NRC will do an analysis to confirm another group's results. The mobile labs have limited sample preparation capability (e.g., cannot perform wet chemistry); therefore, any analyses they perform will be without chemical separation.

The EPA will assume DOE's role of coordinating FRMAP radiological monitoring and assessment activities before the long-term recovery of the emergency begins. Officials of the DOE and EPA need to coordinate closely to determine when this transfer of authority is appropriate.

As defined in the Federal Radiological Emergency Response Plan (Fed. Reg. 1985), EPA's responsibilities for assisting federal, state, and local governments, in addition to assuming DOE responsibilities in the recovery phase, include the following:

- During the initial or emergency phase of the accident, provide personnel, equipment, and laboratory support to assist DOE in offsite monitoring.
- Assess the nature and extent of the environmental hazard.
- Provide guidance to federal agencies and state and local governments on acceptable emergency levels of radioactivity and radiation in the environment.
- Assist the CFA in developing recommended measures to protect public health and safety.

4.0 PLANNING FOR [illegible] [illegible]

The primary purpose of an emergency environmental sampling and analysis program at radioactive material facilities is to provide information on the amount and location of a release of radioactive material. This information also needs to be provided to the general public and the news media. In planning a program to meet these purposes, facilities need to consider the following: the type of sampling and analysis applicable for the three emergency phases, staffing requirements, methods for defining sample collection and measurement locations, equipment and supply requirements, sample collection procedures, field measurement methods, coordination with offsite agencies, recordkeeping requirements, and QA requirements. Each of these topics is presented in some detail in this section.

4.1 THREE PHASES OF AN EMERGENCY

The discussion of emergency environmental sampling and analysis is typically divided into three phases - initial or early, intermediate, and long-term recovery (IAEA 1987). A brief description of the type of sampling and analysis that would be performed for each phase is provided in the following sections.

4.1.1 Initial Phase

Within a few hours after an accident, the facility will need to supply information on the amount and location of released material to news media, public health officials, and responsible regulatory agencies. As discussed in Section 1.0, most accidents at radioactive material facilities involving airborne releases would likely occur rapidly with little warning and be of short duration. Facilities would probably not be able to dispatch an offsite field monitoring team rapidly enough to perform plume tracking or obtain air samples from the plume. Therefore, in the initial phase of an emergency, the primary function of the field monitoring teams would be to determine the extent of the release and the ground deposition left by the passing plume.

Field monitoring teams should perform ground surveys using portable survey instrumentation appropriate for the radioactive material released, as discussed in Section 4.4.1. In the highest ground deposition areas, soil and vegetation samples should be collected to get an estimate of concentration levels. Smear samples from any smooth surfaces in the affected area (e.g., surfaces of vehicles) should be performed. Water sampling would not be critical in the initial phase unless the accident involved a liquid release of radioactive materials. In that case, water sampling should be performed if it is possible for contaminated water to enter the drinking water supply.

Air sample filters should be removed from any fixed air sampling stations that are part of a facility's routine environmental surveillance program. Analysis of these samples may provide information on the radioactivity levels in the plume.

Field monitoring teams should screen all environmental samples in the field using portable survey instruments. The highest reading samples determined by the screening should be given priority for sample counting or analysis in the laboratory. Such screening should be done in low-background areas.

When environmental samples come to the laboratory from the field, supervisory personnel should decide the type of analysis that should be performed on each sample. During the initial phase of the emergency, soil and vegetation samples would be the primary samples collected. Gross alpha, beta, and gamma counting or gamma spectroscopy analysis would be initially performed on the samples to determine relative levels of activity in the environment. Section 4.4.2 provides information on what instrumentation to use based on the type of radioactive material released.

4.1.2 Intermediate Phase

In the intermediate phase, information is needed to locate areas that must have restricted access or be decontaminated. In addition, the facility will need to provide follow-up information on the release to news media, public health officials, and responsible regulatory agencies. During the intermediate phase, time constraints would not be as great, allowing more time for planning. The objective of this phase is to better define the radiological conditions in the affected area. This should be accomplished by performing more detailed ground surveys, more air sampling to determine the extent of resuspension from deposited material, and sampling and analysis of water, milk, and food samples from the affected area to determine the potential dose impact on humans.

Air sampling should be performed to determine whether resuspension of deposited material is a concern. This can be accomplished by collecting grab samples in the areas of highest activity. If there is a fixed routine air sample station located in the affected area, the air sample filter should be periodically changed and analyzed. A continuously operating air sampler should be established in the affected area to better document resuspension levels.

Soil and vegetation sampling should be continued in this phase. Soil sampling should be used to determine ground deposition levels. Vegetation sampling should include collection and analysis of both edible and other local vegetation.

All affected bodies of water should be sampled, concentrating first on drinking water supplies. This would include water bodies contaminated by a direct liquid release or an airborne release.

If milk could be a significant pathway for human exposure based on the type and amount of radioactive material released, samples of milk produced from cows in the affected area should be collected and analyzed.

4.1.3 Long-Term Recovery

The long-term recovery phase should involve sampling and analysis to determine when the public can resume use of certain areas or when restricted land can again be used for pasture or for growing crops. Such sampling would likely follow cleanup and decontamination efforts.

4.2 EMERGENCY ORGANIZATION

A facility's emergency coordinator needs to identify personnel to serve as field monitoring team members during an emergency as well as supervisory personnel who are responsible for dispatching and controlling field monitoring teams and interpreting results obtained by the teams. To maintain an effective program, facilities should have procedures established for assembling, dispatching, and directing field monitoring teams. A discussion of a typical organization for an emergency environmental sampling and analysis program and development of procedures for effectively using this organization are provided in this section.

4.2.1 Field Monitoring Teams

A facility should have enough trained personnel to dispatch at least two field monitoring teams in an emergency. A typical team should consist of a facility health physics (HP) technician and a driver. The HP technician should be responsible for taking exposure rate readings, collecting environmental samples, recordkeeping, reporting monitoring results, contamination control, and monitoring the team's radiation exposure. The driver should assist with map reading and locating sampling points.

Facilities should have procedures that address the actions of the field monitoring teams and supervisory personnel. Personnel should be trained in using the procedures. The procedures should address the following areas:

- Method of assembling field monitoring teams and obtaining necessary equipment in an emergency - Qualified personnel need to be identified and a plan is needed for calling in personnel in a timely manner should the emergency occur on a back shift.

- Field monitoring team preparation - Guidance should be provided for performing inventories of equipment and supplies before dispatch into the field. Operability checks should be performed on portable radiation survey instruments and air samplers. Instruments should be checked for current calibration. If kits are routinely inventoried and sealed after each inventory, supplies need not be checked before team dispatch. However, operability checks still need to be performed on survey instruments and air samplers.

- Field monitoring team dispatch - Field monitoring teams should receive a briefing from supervisory personnel before being dispatched into the field. The briefing should include information on where to initiate surveys, sample locations, how often to report field measurement data, protective clothing requirements, and exposure control concerns.

- Finding sample locations rapidly - If the facility has predefined sample locations, the locations should be marked on team maps. Teams also need to be trained to find routine environmental monitoring stations around the facility.

- Contamination control - All air samples and environmental samples should be double-bagged and sealed to prevent cross-contamination. Field monitoring teams should keep the inside of their vehicles as free from contamination as possible by surveying themselves and articles when they reenter the vehicle after taking measurements or collecting samples. High-level samples should be stored such that they do not constitute a hazard to the field monitoring team, otherwise, samples should not be collected. Teams should survey and decontaminate their vehicles after returning from the field. Decontamination residues should be disposed of as radioactive waste, if necessary.

- Personnel exposure control - Prior to team dispatch, each team should be given an exposure limit and guidance on whether protective clothing should be worn. Teams should be responsible for tracking their own exposures, using self-reading dosimeters and notifying their supervisors if they approach their limits. Supervisory personnel should then decide whether to extend their dose limits or replace the team.

- Additional support - The procedure should address all nearby facilities that could provide manpower and equipment support, should additional resources be needed to perform emergency environmental monitoring. For example, the facility's corporate office could provide support. This support would be in addition to any state and federal assistance.

4.2.2 Supervisory Personnel

Facilities should have one to two supervisory personnel available in an emergency who are responsible for briefing field monitoring teams before dispatch, controlling team activities, and debriefing teams on their return from the field. Supervisory personnel could be facility environmental managers or HP supervisors. Other responsibilities would include ensuring that samples are delivered to those who perform the analyses.

4.3 DEFINING SAMPLE COLLECTION AND MEASUREMENT LOCATIONS

Planning should be done to determine the best sample collection and measurement locations for a given release scenario in order to facilitate the acquisition of environmental data soon after an actual release. Locations should be based on factors that affect the potential for exposing the public. These factors include demographics, terrain, land use, prevailing wind direction, source term, and the release path. Locations should be accurately described so that they are easily located by the field monitoring teams. Sample locations are commonly referenced to a grid system using roads and landmarks such as mile markers, road signs, and numbered telephone poles.

A reference coordinate system can be used to subdivide the area surrounding the facility. Reference locations are thus established for obtaining offsite radiological measurements and samples of environmental media. The reference coordinate system can be overlaid on a map showing the major topographical features of the area including roads and bodies of water. Figure 4.1 shows a reference coordinate system that divides the area around the plant into 16 sectors with circular grids nominally located at intervals of 1, 2, and 5 miles. The sectors are labeled A through R, with the letters I and O omitted so as not to confuse them with a number designator. Alternatively, the sectors can be designated by degrees taking north as 0° and 360°. The numbers and locations of the predesignated sample collection and measurement locations can be determined by the facility based on special populations in the area (e.g., schools, hospitals, and nursing homes), nearby residences, key agricultural areas, and other factors as applicable.

The expected offsite impact would be confined to a relatively small radius (<1 mile) for most accidents at radioactive material facilities. A guideline to determine the extent of the reference coordinate system coverage might be the distance from the plant to the points where the projected

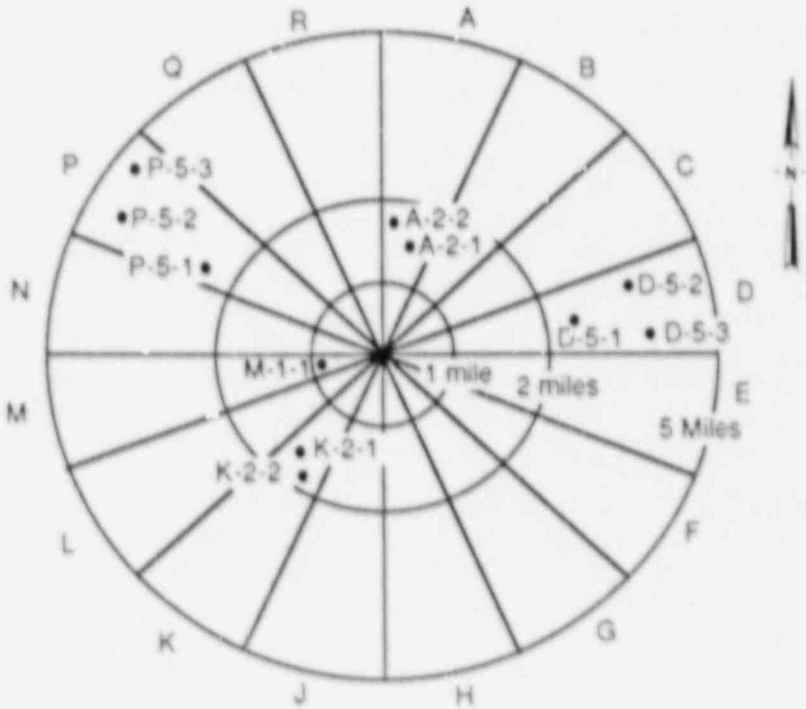

FIGURE 4.1. Typical Design of Radial Grid for a Reference Coordinate System

offsite doses from a potential accident would be equal to or greater than the lower dose values of the EPA Protective Action Guidelines (1 rem to the whole body or 5 rem to the thyroid) (EPA 1980). In situations where many offsite agencies could become involved with the offsite monitoring, designation of the locations should be unique to avoid confusion about where samples or measurements were taken. Preferably, agencies should use the same designation system. However, if different systems are used, care should be taken to avoid having one sample designator (e.g., M-1-1) refer to two different locations.

The approximate boundaries of a contaminated area could be determined using the reference coordinate system as a basis for field measurements. More precise determination of contaminated areas would require establishing survey grids in the field. Appendix B provides guidance for using radial and rectangular grids to define contaminated areas. Field methods for measuring distances and mapping survey areas are also included.

4.4 EQUIPMENT AND SUPPLIES

Equipment and supplies necessary for an emergency environmental sampling and analysis program include appropriate portable survey instruments for performing radiation measurements in the field and in the laboratory, air sampling equipment, sample collection supplies, personal protection supplies, and vehicles for use by the field monitoring team. Equipment and supplies need to be located in areas that would be readily accessible during an emergency. Appendix C provides a typical inventory list of emergency monitoring equipment for an offsite field team.

4.4.1 Portable Survey Instruments

Portable survey instruments have the advantage of providing the earliest information on radioactive material deposited by a release. The types of portable survey instruments used for emergency monitoring would depend on the type of radioactive material that a facility could release. A general discussion of the types of alpha, beta, and gamma survey instruments that could be used for environmental monitoring are provided. Operational aspects of their use are described for making quantitative estimates of deposited activity.

Typical alpha survey instruments that can be used to measure radionuclides, such as uranium, $^{238,239}Pu$, $^{242,243,244}Cm$, ^{241}Am, and ^{210}Po, include the ZnS scintillation detectors, gas proportional counters, and air proportional counters. The short range of alpha particles in air (3.5 to 4.8 cm for 5 to 6 MeV alphas) combined with the shielding effects of small amounts of moisture, dust, and vegetation make field measurements of alpha contamination difficult and unreliable. At best, a relative indication of the amounts of deposited activity present will be obtainable. With these instruments, the probe must be held as close to the surface being measured as possible, and care must be exercised to avoid contaminating or damaging the probe by contacting the contaminated surface. All three types of instruments require that the probe be closely monitored for damage in order to ensure reliable readings.

If the window of a ZnS detector is punctured, the incoming light can cause spurious counts that will bias the reading. The probe should be held up to a light source periodically to check for holes in the window. The efficiency of a gas proportional detector may not be significantly degraded by a pin-hole sized puncture of the window. An air proportional alpha survey instrument is sensitive to high humidity, steam, or excessive moisture which may cause aberrant readings. Kenoyer et al. (1986) provide additional information on the performance of air proportional alpha survey instruments and other portable survey instruments in high humidity environments. Because of the fragile nature of alpha survey instruments, spare instruments need to be provided if they are included as part of a field team's kit.

Using portable alpha instruments to survey large contaminated areas may not be desirable because of the uncertainties associated with the alpha measurements and the time and manpower required. An instrument has been developed to measure the low-energy photons emitted by ^{239}Pu (13 to 20 keV) and ^{241}Am (60 keV). The Field Instrument for Detection of Low-Energy Radiation (FIDLER) uses a 12.7-cm-diameter by 0.2-cm-thick sodium iodide (NaI) crystal. This instrument may provide a more rapid and reliable measurement of plutonium and americium contamination over a large area than would alpha survey instruments. Tinney, Koch, and Schmidt (1969) found that the FIDLER had a greater count rate at a source-to-detector distance of 27 cm compared to contact readings with a portable alpha survey instrument for a source distributed over relatively flat terrain. Commercially available sodium iodide detectors with thin windows (approximately 7 mg/cm^2) and portable germanium spectrometers could also be used for field detection of the low-energy photons. All of the instruments discussed above could also be used to measure the 35 keV photon from ^{125}I.

Measurement of beta emitters such as ^{90}Sr-Y and ^{238}U in the environment is most commonly done with a Geiger-Mueller (GM) detector because of better sensitivity, fast response times, and durability. Field measurements for beta contamination must be done with the probe as close as possible to the surface. Quantitative determination of deposited beta activity can have a large uncertainty because of variable particle attenuation and conditions where the source/detector geometries differ from the calibration geometry of the instrument. Plastic scintillators and proportional probes can also be used to make beta field measurements.

Tritium cannot be reliably measured in the field using portable survey instruments because of low-energy betas (E_{avg} = 5.6 keV). Tritium betas have approximately a 2-cm range in air and cannot penetrate detector windows. A windowless, gas flow, proportional counter probe has been used in the field for counting smear samples (Jensen and Martin 1988).

Photons emitted by ^{125}I, ^{131}I, ^{134}Cs, ^{137}Cs, and ^{243}Cm are more easily measured in the environment than alpha and beta radiations. Because of their sensitivity and short response times, GM and NaI detectors can be effectively used to locate contaminated areas. Dose rate measurements, if desired, can be estimated with GM, NaI, and ionizati · chamber instruments. Allowance must be made for the energy dependence of t! GM and NaI detectors. Source/detector geometry can affect the accuracy of the measurements when it differs from the calibration geometry.

Relationships have been developed between portable survey instrument readings and the amounts of deposited radioactive material for gamma-emitting radionuclides. The International Atomic Energy Agency (IAEA) provided information to correlate contamination on vegetation, in water and milk, and on the ground, with survey instrument readings (IAEA 1966; IAEA 1974). But conversion factors derived in the two IAEA reports may not be appropriate to use with present day instrumentation. Two reasons for this are the differences in contemporary instrument design and uncertainties associated with the source/detector geometries. However, the methods used to make the measurements could be used in developing updated conversion factors.

Tables 4.1 and 4.2 contain factors to convert instrument rates to activity concentrations for vegetation and liquid samples, respectively. This data is taken from preliminary work by PNL in support of FRMAP for DOE Region 8. Vegetation and liquid samples were spiked with known concentrations of ^{90}Sr-Y, ^{131}I, or ^{137}Cs. Measurements were taken with commercially available GM tubes (cylindrical and pancake probes) and sodium iodide detectors (μR-meters). Dimensions and wall thicknesses for each instrument probe are shown in Table 4.3.

The factors in Table 4.1 were derived by a method using spiked vegetation similar to the method used in IAEA (1966). A 30 cm x 40 cm plastic bag was half filled (approximately 0.5 kg) with the spiked vegetation. The air was compressed out of the bag and the bag sealed. The bag was folded around the probe and the reading allowed to stabilize (approximately 10 to 15 seconds). A portable instrument reading would be divided by the appropriate conversion factor in Table 4.1 to estimate the activity concentration in μCi/kg.

TABLE 4.1. Conversion Factors for Vegetation Samples Using Selected Portable Survey Instruments

Isotope	Pancake GM, cpm/μCi/kg	Sliding Tube Type GM, cpm/μCi/kg		μR Meter, μR/h/μCi/kg
		Open	Closed	
Background	50 cpm	50 cpm	50 cpm	10 μR/h
^{137}Cs	150	50	50	15
^{131}I	80	30	NR[(a)]	NR
^{90}Sr-Y	600	300	NR	NR

(a) NR = No response

TABLE 4.2. Conversion Factors for Liquid Samples Using Selected Portable Survey Instruments

Isotope	Pancake GM, cpm/μCi/L	Sliding Tube Type GM, cpm/μCi/L		μR Meter, μR/h/μCi/L
		Open	Closed	
Background	50 cpm	50 cpm	50 cpm	10 μR/h
^{137}Cs	400	200	200	125
^{131}I	450	300	125	300
^{90}Sr-Y	1200	300	NR[(a)]	NR

(a) NR = No response

TABLE 4.3. Dimensions and Wall Thickness of Portable Instrument Probes

Instrument	Dimensions of Probe	Wall Thickness, mg/cm^2
Cylindrical GM	3.2-cm-dia, 14 cm long	30
Pancake GM	5.1-cm-dia window	1.4 -2.0
NaI (μR meter)	5.1-cm x 5.1-cm crystal	446

The data in Table 4.2 was obtained by placing the probe over the center of the 3.8 L sample container. The instrument probe or the sample container was sealed in a plastic bag. The mean of three readings was recorded and corrected for background. A portable instrument reading would be divided by the appropriate conversion factor in Table 4.2 to estimate the activity concentration (μCi/L). For easy reference in the field, the instrument count rate versus activity concentration can be plotted as shown in Figures 4.2 and 4.3.

Tables 4.4 and 4.5 list the minimum detectable concentrations for vegetation and liquid samples based on the background count rates shown in Tables 4.1 and 4.2. The minimum detectable concentrations (MDCs) were calculated by

$$\mathrm{MDC} = \frac{3 \times \text{Background Count Rate}}{\text{Specific Conversion Factor from Tables 4.1 and 4.2}} \quad (4.1)$$

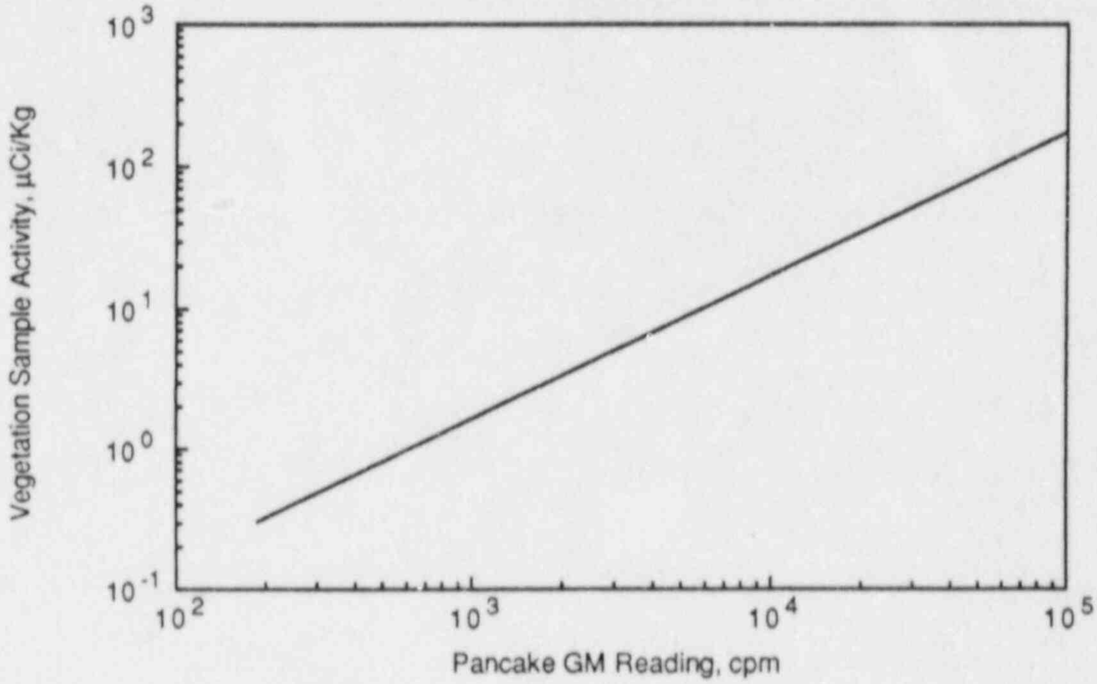

FIGURE 4.2. Pancake GM Reading Versus Vegetation Sample Activity for ^{90}Sr-Y

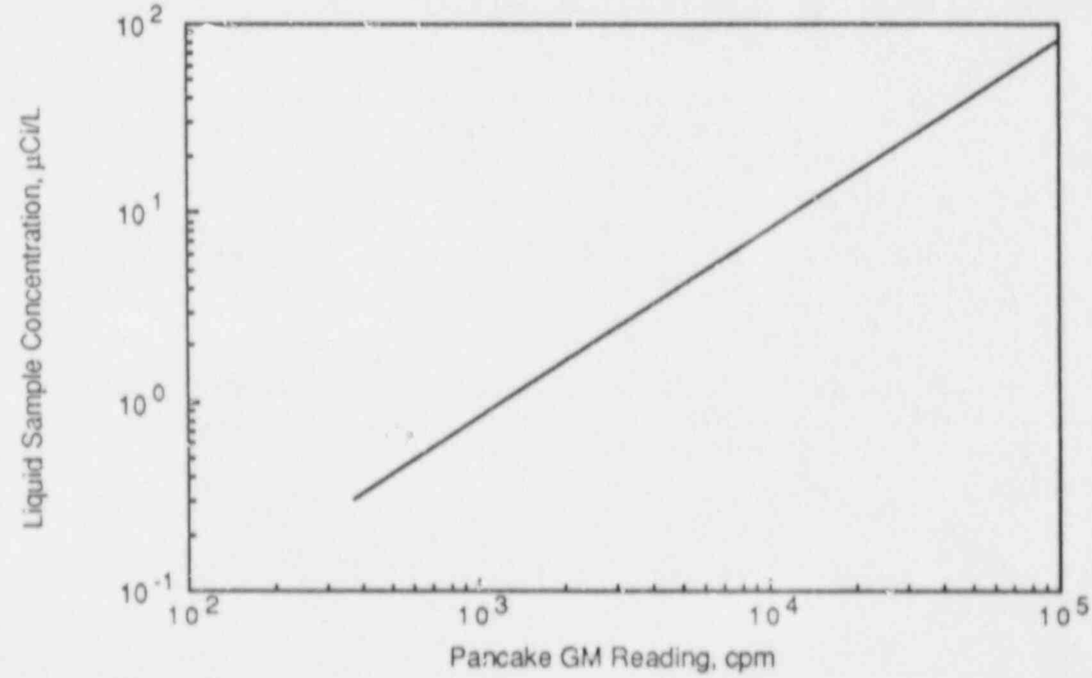

FIGURE 4.3. Pancake GM Reading Versus Liquid Sample Concentration for ^{90}Sr-Y

TABLE 4.4. Minimum Detectable Concentrations (μCi/kg) for Vegetation Samples Using Selected Portable Survey Instruments

Isotope	Pancake GM	Sliding Tube Type GM Open	Sliding Tube Type GM Closed	μR Meter
Background	50 cpm	50 cpm	50 cpm	10 μR/h
^{137}Cs	1	3	3	2
^{131}I	2	5	NR[a]	NR
^{90}Sr-Y	0.3	0.5	NR	NR

(a) NR = No response

TABLE 4.5. Minimum Detectable Concentrations (μCi/L) for Liquid Samples Using Selected Portable Survey Instruments

Isotope	Pancake GM	Sliding Tube Type GM Open	Sliding Tube Type GM Closed	μR Meter
Background	50 cpm	50 cpm	50 cpm	10 μR/h
^{137}Cs	0.4	0.8	0.8	0.2
^{131}I	0.3	0.5	1.2	0.1
^{90}Sr-Y	0.1	0.5	NR[a]	NR

(a) NR = No response

TABLE 4.6. Conversion Factors and Minimum Detectable Concentrations (MDC) for Vegetation Samples Based on Portable Spectrometer Measurements with a NaI Detector

Isotope	Conversion Factor, cpm/μCi/kg	Background in Region of Interest, cpm	MDC, μCi/kg
^{137}Cs (662 keV)	3430	120	0.11
^{131}I (364 keV)	4300	345	0.24

TABLE 4.7. Conversion Factors and Minimum Detectable Concentrations (MDC) for Liquid Samples Based on Portable NaI Spectrometer Measurements

Isotope	Conversion Factor, cpm/μCi/L	Background in Region of Interest, cpm	MDC, μCi/L
^{137}Cs (662 keV)	21,800	120	0.017
^{131}I (364 keV)	27,800	345	0.038

Portable spectrometers utilizing NaI or solid state detectors can be used to measure the photon energy spectrum. Examples are found in Tables 4.6 and 4.7 of isotope-specific conversion factors and minimum detectable concentrations determined from sodium iodide spectrometer measurements of vegetation and liquid samples spiked with ^{137}Cs and ^{131}I. These data are also taken from preliminary work performed by PNL for the DOE Region 8 FRMAP. Measurements were made with a portable spectrometer using a 5.1 cm x 5.1 cm sodium iodide detector. The conversion factors and minimum detectable concentrations were determined by the same method used for the portable survey instruments (Tables 4.1, 4.2, 4.4, and 4.5).

4.4.2 Instrumentation for Counting Environmental Samples

Counting environmental samples collected during an emergency involves two phases:

- Rapid assessments in the initial phase of the emergency when sample results are needed quickly to determine the extent of the release - would include gross alpha, beta, and gamma counting of the samples, gamma spectroscopy counting, and rough estimates of activity using portable survey instruments.
- Detailed assessments in the intermediate and long-term recovery phases of the emergency - would include alpha, beta, and gamma analyses and radiochemical separation procedures where necessary.

Discussions of rapid and detailed assessment counting methods are provided below. Information specific to the radionuclides of concern for radioactive material facilities (i.e., ^{3}H, ^{90}Sr, $^{125,131}I$, $^{134,137}Cs$, ^{210}Po, uranium, $^{238,239}Pu$, ^{241}Am, and $^{242,243,244}Cm$) is also provided.

Rapid Assessments

During the initial phase of an emergency, the capability to make gross counts of samples is important from the standpoint of refining the initial field readings or actually providing the initial data. More exact analyses can be undertaken during the intermediate and recovery phases, when rapid assessment is not so critical. Proportional counters, scintillation counters, and semiconductor detectors can be used to make gross measurements of environmental samples with little sample preparation.

Sodium iodide and semiconductor detectors (Ge[Li], HPGe, Silicon Surface Barrier) coupled with the appropriate electronics would be useful in measuring bulk environmental samples containing photon emitters (i.e., ^{125}I, ^{131}I, ^{134}Cs, ^{137}Cs, ^{241}Am, and ^{243}Cm). To optimize the measurement, a fixed and reproducible counting geometry and appropriate calibration are necessary. The counting system should be calibrated with standards in the same geometry as the sample (NCRP 1985). This can be accomplished by "spiking" the sample matrix (e.g., soil, water, and vegetation) with a known amount of radioactive material. Detection efficiencies for the system can then be determined. NaI detectors generally have better detection efficiency than the semiconductors, resulting in shorter counting times. The superior energy resolution of the semiconductor detectors makes them most useful for measuring samples that contain mixtures of photon emitters and for measuring low-energy x-rays.

Proportional counters can be used to rapidly measure the gross alpha and beta activity in solid environmental samples (e.g., soil and vegetation) containing ^{90}Sr-Y, ^{131}I, ^{238}U, $^{238,239}Pu$, and $^{242,244}Cm$. Internal proportional counters where the sample is immersed in the sensitive volume can count both the alpha and beta activity in environmental samples. The counting chamber must be routinely checked for contamination. Radionuclides with sufficiently energetic beta particles, such as ^{90}Sr-Y (E_{max} = 2.27 MeV), can be counted with GM or proportional counters that have a window for contamination control. To optimize the beta detection efficiency, absorption and scattering within the sample, backscattering, source-to-detector distance, and calibration of the system under known and reproducible conditions must be considered.

Liquid scintillation counting can be used to measure gross alpha and beta activity including ^{3}H in water samples without sample pretreatment. The detection efficiency may approach 100% depending on the amount of signal quenching. Liquid scintillation could also be used for rapid analysis of solid samples if the chemical form of the solid is soluble in the cocktail solution. Volchok and dePlanque (1983) describe a combustion procedure for converting solid samples to water for liquid scintillation counting.

Detailed Assessments

A more detailed quantitative assessment of the activity content of the environmental samples will be necessary to accurately estimate the levels of deposited activity. This requires that the sample be in a form suitable for counting to achieve the desired accuracy. The amount of sample preparation depends on factors including whether a single nuclide or mixture of radionuclides was involved and what type of sample will be analyzed. Sample preparation can include diluting, evaporating, ashing, filtering, dissolution, radiochemical separations, and taking sample aliquots.

Radiochemistry manuals referenced below contain examples of commonly used methods for the chemical separation of specific radionuclides from various media. The methods evolved from years of practical application and are considered models of good radiochemical practice. Table 4.8 identifies the analytical procedures contained in each manual by specific radionuclide and environmental media. Analytical procedures for fluorides are also included.

HASL-300 (Volchok and dePlanque 1983), the Environmental Measurements Laboratory Procedures Manual, contains procedures that have been tested over an extended period of time by many chemists and technicians. Nearly all the analytical methods are derived from previously published procedures.

The Eastern Environmental Radiation Facility (EERF) is a field laboratory operated by the Office of Radiation Programs of the U.S. Environmental Protection Agency. The procedures in the EERF manual, EPA 520/5-84-006 (Lieberman 1984), have been subject to intra- and interlaboratory comparisons. Intralaboratory comparisons are accomplished through replicate analyses on every tenth sample, and weekly blind and spiked samples are analyzed. The EERF participates in three interlaboratory comparison programs conducted by the EPA, World Health Organization, and the IAEA.

The Environmental Monitoring and Support Laboratory-Las Vegas (EMSL) has prepared a manual, EMSL-LV-0539-17, entitled Radiochemical Analytical Procedures for Analysis of Environmental Samples (Johns et al. 1979). The EMSL conducts the EPA National Quality Assurance Program described in EPA 600/4-78-032 (EPA 1978).

The EPA National Environmental Research Center in Cincinnati, Ohio, has compiled the manual, Procedures for Radiochemical Analysis of Nuclear Reactor Aqueous Solutions (Krieger and Gold 1973). Standard procedures from the American Society for Testing and Materials (ASTM) have been adopted for barium, iodine, iron, manganese, and tritium. Other procedures have been developed from previously published works.

The Prescribed Procedures for Measurement of Radioactivity in Drinking Water, EPA-600/4-80-032 (Krieger and Whittaker 1980), has been developed by the Environmental Monitoring and Support Laboratory in Cincinnati, Ohio and the Environmental Monitoring Systems Laboratory in Las Vegas. The manual includes applicable procedures from other sources including the American Public Health Association, ASTM, EPA, and DOE.

The ASTM Annual Book of Standards, Volume 11.02 contains procedures for analyzing radioactive material in water (ASTM 1986). Methods of Air Sampling and Analysis by the American Public Health Association contains analytical procedures for particulates, iodines, and tritium (Katz 1977).

4.4.3 Sample Collection Equipment and Supplies

Each field team kit should have a small shovel or trowel for collecting soil samples and grass clippers for collecting vegetation samples. Plastic

TABLE 4.8. Radionuclides and Environmental Media Covered by Major Radiochemical Procedures

Nuclide	Media	Department of Energy Laboratory (1)[a]	Environmental Protection Agency Laboratories (2, 3, 4, 5)	American Society of Testing and Materials (6)	American Public Health Association (7)
^{3}H	Air		2		7
	Water	1	2, 3, 4, 5	6	
	Soil		5		
	Vegetation	1	2, 5		
	Milk		2, 5		
^{90}Sr	Air				7
	Water	1	2, 3, 4, 5		
	Soil	1	2, 5		
	Vegetation	1	2, 5		
	Milk	1	2, 5		
$^{125,131}I$	Air				7
	Water		3, 5	6	
	Soil				
	Vegetation				
	Milk	1	5		
$^{134,137}Cs$	Air				
	Water	1	3, 4	6	
	Soil	1			
	Vegetation	1			
	Milk	1			
^{210}Po	Air	1	2		
	Water	1	5		
	Soil	1	2, 5		
	Vegetation	1	5		
	Milk				

TABLE 4.8. (contd)

Nuclide	Media	Department of Energy Laboratory (1)[a]	Environmental Protection Agency Laboratories (2, 3, 4, 5)	American Society of Testing and Materials (6)	American Public Health Association (7)
Uranium	Air	1	2, 5		
	Water	1	2, 4, 5	6	
	Soil	1	2, 5		
	Vegetation	1	2, 5		
	Milk		2, 5		
$^{238,239}Pu$	Air	1	2, 5		7
	Water	1	2, 4, 5	6	
	Soil	1	2, 5		
	Vegetation		2, 5		
	Milk		5		
^{241}Am	Air	1			
	Water	1	4		
	Soil	1	5		
	Vegetation		5		
	Milk				
$^{242-244}Cm$	Air	1			
	Water		4		
	Soil				
	Vegetation				
	Milk				
Fluorides	Air	1			7
	Water	1		6	
	Soil	1			
	Vegetation				
	Milk				

TABLE 4.8. (contd)

(a) Radiochemical procedures are found in the following manuals designated by numbers 1-7.

(1) EML Procedures Manual, HASL-300 (Volchok and dePlanque 1983)
Environmental Measurements Laboratory
U.S. Department of Energy
376 Hudson Street
New York, NY 10014

(2) Radiochemical Analytical Procedures for Analysis of Environmental Samples, EMSL-LV-0539-17 (Johns et al. 1979)
U.S. Environmental Protection Agency
Environmental Monitoring and Support Laboratory
Las Vegas, NV 89114

(3) Procedures for Radiochemical Analysis of Nuclear Reactor Aqueous Solutions, EPA-R4-73-014 (Krieger and Gold 1973)
U.S. Environmental Protection Agency
National Environmental Research Center
Cincinnati, OH 45268

(4) Prescribed Procedures for Measurement of Radioactivity in Drinking Water, EPA-600/4-80-032 (Krieger and Whittaker 1980)
U.S. Environmental Protection Agency
Environmental Monitoring and Support Laboratory
Cincinnati, OH 45268

(5) Radiochemistry Procedures Manual, EPA 520/5-84-006 (Lieberman 1984)
U.S. Environmental Protection Agency
Eastern Environmental Radiation Facility
Office of Radiation Programs
Montgomery, AL 36109

(6) 1986 Annual Book of ASTM Standards (ASTM 1986), Section II, Volume 11.02, Water.

(7) Methods of Air Sampling and Analysis, Second Edition, American Public Health Association Intersociety Committee (Katz 1977).

containers and bags should be provided for storing approximately 24 environmental samples. Containers that can be sealed tightly should be provided for collection of liquid samples. Kits should also contain keys to locked gates that might prevent access to roads near the plant and to environmental monitoring stations around the facility that may be locked.

4.4.4 Administrative Aids

Administrative aids would assist the field team members and supervisory personnel in defining sample locations and keeping track of all samples collected. Maps of the area several miles around the facility should be provided to the field teams and supervisory personnel. The maps should show the topography, main highways, secondary roads, population centers, bodies of water, and any predefined grid system developed for defining sampling locations. An enlarged version of the map could be used by supervisory personnel to record radiation levels and sample results at the field team controlling point.

Field team kits should include copies of logs or forms for recording exposure rate readings and environmental samples collected. Tags should also be included to label air and other environmental samples. Logs and tags are discussed in more detail in Section 4.8.

4.4.5 Personal Protection Equipment and Supplies

Field team kits should have at least two full sets of protective clothing. Each team member should be equipped with a thermoluminescent dosimeter (TLD) to provide a permanent record of exposure. A self-reading dosimeter should be provided to each team member when the release involves gamma emitters. A typical range for the dosimeter would be 0 to 200 mR or 0 to 500 mR.

4.5 SAMPLE COLLECTION PROCEDURES

The emergency environmental sampling and analysis program should include procedures for collecting soil, vegetation, water, snow, milk, and air samples. For many facilities, this may be as simple as stating that routine environmental sample collection procedures will be followed. The physical sample collection process will probably not vary between routine and emergency situations.

However, determination of appropriate sampling locations will vary between routine and emergency environmental sampling. In routine environmental sampling, samples would be collected in open areas away from any influences that may bias the results, such as along roads where vehicle traffic could influence the deposition pattern. Because depositions are expected to be uniform over the long term and widespread for routine environmental releases, sampling in open areas would be appropriate. During an emergency, samples must be collected in areas where portable survey instrument measurements indicate elevated activities. This may include wooded areas,

areas near buildings, and areas along roads which would not be appropriate sampling locations when collecting routine environmental samples.

Contamination control considerations are important in an emergency situation. Experience and practice in contamination control measures will minimize the potential for cross-contamination of samples during collection and handling. Samples should be double-bagged and sealed in clean sample bags or containers to prevent cross-contamination or loss of the sample. Tools such as shovels or grass clippers should be cleaned and surveyed after each sample is collected if they are to be reused. Disposable tools (e.g., plastic scoops to collect soil samples) may be useful for sample collection. Samples should be securely stored for transport. Vehicles that transport samples should contain specific areas for storing clean and potentially contaminated items. Container material should be chosen to minimize the loss of activity through adsorption or other chemical reactions. Storing samples for extended periods should ensure that the sample remains representative of the original environmental conditions.

Soil, vegetation, water, snow, milk, and air samples are the primary types of environmental media that facility field teams would typically collect during an emergency. Collection methods for each of these media are discussed below.

4.5.1 Soil Sampling

To assess the deposition following a release of airborne radioactive material only the uppermost layers of soil would need to be sampled in most cases. Exceptions that might warrant sampling to greater depths would be if a large amount of precipitation fell soon after the release or if there were a liquid release onto the ground near a facility. Soil samples should be collected from areas that are relatively free of vegetation, rocks, and roots. However, this may not always be possible because emergency sampling needs to be performed in areas of elevated activity. If vegetation cover is present, it should be sampled with the soil and the analytical results combined to measure the total deposition.

Examples of specific methods used to collect soil samples are found in the U.S. Atomic Energy Commission (AEC) Regulatory Guide 4.5 (AEC 1974). One method used at the Environmental Measurements Laboratory (EML) is considered acceptable for sampling most soil types except sandy soils. The method uses a topsoil cutter (7.9-cm radius) that takes a 5-cm-deep sample. A barrel auger is also used. Experience at the EML has shown that a total sample area of approximately 460 to 930 cm^2 provides a reasonably good estimate of the deposited activity if a composite of a number of samples is used. The samples are taken along a straight line transect approximately 30 cm apart. The cutter is pressed into the soil and rotated to allow the core to be removed and placed in a sample container. The barrel auger can then be used if a greater sample depth is warranted to provide a vertical profile of the activity distribution.

A method to sample loose sandy soils is in use at the Nevada Test Site. The procedure uses a ring (12.7 cm internal diameter x 2.5 cm deep) that is pressed into the soil. Soil inside the ring is removed and put into a sample container. The soil outside the ring is removed and the ring is again pushed into the ground and another sample taken from inside the ring. The procedure is repeated until the desired depth is reached. A minimum of five samples are taken along a straight line transect.

The survey of environmental sampling capabilities of facilities, states, and DOE contractors revealed two generally accepted soil sampling methods. Most organizations collect soil samples from a 0.09 m^2 (1 ft^2) area down to a depth of approximately 1.3 cm (1/2 in.). Samples are collected using a shovel or trowel, then placed in a plastic container. This would result in a sample weighing approximately 1.7 kg (3.7 lb) depending on the type of soil. Several DOE contractors collect a soil sample from an approximate 25 m^2 (approximately 270 ft^2) area. Within this area, five separate samples (each 10 cm in diameter and 1 cm deep) are collected and analyzed as one sample. Samples are collected using a "cookie cutter" device and placed in a container. This composite sample would weigh approximately 0.5 kg (1.1 lb).

In some situations where significant ground depositions have occurred, core soil samples may be taken immediately after the release to provide background concentrations at depths down to 10 to 12 in. Additional core samples can be taken periodically after the release to determine migration of the initial deposition into the soil.

4.5.2 Vegetation Sampling

Samples are commonly obtained by clipping the vegetation close to the soil to simulate a grazing animal's intake. The amount of soil collected with the vegetation should be minimized. Samples typically weigh 500 to 1000 grams (wet weight) and are taken from a unit area of 0.09 m^2 (1 ft^2) or 1 m^2 (10.8 ft^2). Some general considerations for collecting vegetation samples include the following:

- Clip grass samples as close to the surface as possible without getting roots and soil in the sample.
- When collecting leafy vegetation samples, collect only the leaf portion, leaving the stems and roots behind.
- When collecting leaves from trees or bushes, avoid collecting limbs, pine needles, and other materials that will be difficult to ash.

Based on the survey of sampling capabilities of facilities, states, and DOE contractors, collecting grasses from a 1-m^2 area will give an adequate sized sample of approximately 1 kg (2.2 lb). When sampling other types of vegetation (e.g., corn), collecting samples from an area the size of 1 m^2 would not be appropriate. Sampling by weight would be more appropriate.

4.5.3 Snow Sampling

Snow should be sampled to provide an indication of the extent of the ground contamination if a release occurs in an area with snow cover. The survey of facility, state, and DOE contractor sampling procedures indicated that a typical snow sample should be collected from an area of approximately 1 to 2 m^2 to a depth of 2.5 cm. This will result in a water sample of approximately 2 to 3 L, which will be an adequate size for analysis. If the snow is powdery and newly fallen, a larger area should be sampled (approximately 2 m^2), compared to icy snow where an area of 1 m^2 should be adequate. Icy or heavy wet snow will have approximately twice the water content of powdery snow.

If any new snow has fallen during or following the release, field teams must sample deep enough to collect the contaminated layer. Another concern during snow sampling is drifting snow. Snow samples should be collected in areas that are not prone to drifting, if possible.

4.5.4 Water Sampling

Sampling done by facility field teams would typically include water samples from any streams, rivers, ponds, drainage ditches, or standing water locations in the area affected by the release. Such surface water samples would be collected by dipping sample containers in the water until full. Before sampling, sample containers should be rinsed several times with water from the body of water to be sampled. This rinse water should be disposed of downstream of the sample collection point if sampling from a stream or river. When collecting the samples, care should be taken to avoid dredging up sediments from the bottom of the stream, river, lake, or pond. The survey of facility, state, and DOE contractor sampling procedures showed that sample volumes are typically 1 L or 3.8 L (1 gal). If the body of water being sampled is not deep enough to use the sample container, a dipper can be used to pour the sample into the container.

Sample containers for water sampling ould be made of chemically resistant glass or polyethylene or polypropylene plastics. If sampling for tritium, glass containers should be used since tritium can permeate through plastic containers and cause cross-contamination problems.

4.5.5 Milk Sampling

Samples should be collected from farms in both upwind and downwind directions. Upwind samples should be used as background samples. Sampling in the downwind direction should extend beyond the area of known contamination if additional dairy farms are in the vicinity. However, milk samples from the affected area should not be diluted with samples from unaffected areas. No special procedures are required for sample collection but, because milk is perishable, sample preservation may be necessary. Several chemicals may be used to preserve a milk sample including formaldehyde, citrates, sodium ethylmercuithiosalicylate, and thimerosal (Kathren 1984; Lamanna et al. 1965).

Alternatives to chemical preservation of samples include refrigeration and field concentration using ion exchange resins (Klement 1982).

Metal and glass containers are not recommended for milk collection because adsorption to the container walls can adversely affect the representativeness of the sample (Kathren 1984). Clean polyethylene containers are commonly used to minimize adsorption.

The survey of emergency environmental sampling procedures provided the following information on milk sampling:

- Milk samples taken in the affected area should be from cattle that have been grazing on the pasture in the area and not those on stored feed.

- Samples should be collected from blending/holding tanks after mixing. A determination needs to be made whether all the milk in the tanks is from cattle grazing in the affected area. Caution must be exercised to avoid biological cross-contamination of blending tanks or herds on neighboring farms by individuals assigned to collecting the milk.

- Milk samples preserved by chemical additives should be marked--"Milk sample preserved with chemical additive not for human consumption."

- Of the facility, state, and DOE contractor procedures reviewed, all collected 3.8-L (1-gal) samples. A total of five procedures discussed milk sampling, but only one added a preservative (formaldehyde) to milk samples in the field. The other procedures recommended getting the samples to the laboratory as soon as possible or putting the sample on ice during transit.

4.5.6 Air Sampling

During an emergency, radioactive material facilities are likely to perform two types of air sampling. Their first priority would be to change the air filters from any continuously operating air samplers located around the facility. Changeout of continuously operating air samplers should be done according to procedures identified in the facility's routine environmental surveillance program.

The second type of air sampling would be the collection of grab samples which can provide information on airborne concentrations as a result of resuspension from ground contamination. Based on the survey of facilities, state, and DOE contractors, grab air samples are generally done using a low volume air sampler operating at a flow rate of 3 to 5 cfm for approximately 10 minutes to get a total sample volume of approximately 30 to 50 ft^3. Use of high volume air samplers (50 to 55 cfm) would also be appropriate. Facilities should determine whether they are collecting an adequate sized sample to meet their required detection limits.

The remainder of this section includes information on good practices in the collection of air samples. Air sampling for tritium, iodines, and particulates differs mostly in the media collected. In general, sampling for these constituents involves drawing a known volume of air through an appropriate collection device. Several references are available that describe the desirable characteristics of the collection devices and sampling systems (NCRP 1976; Corley et al. 1981; Kathren 1984; IAEA 1966; IAEA 1974). Many commercial units are available and in use for routinely collecting these contaminant species.

Air samples should be taken at a sufficient height to minimize dust loading. A height of 1.5 m (approximately 5 ft) has been suggested as adequate (Corley et al. 1981). The sample volume must be measured which is routinely done using a totalizing device or flow rate indicator (rotometer). If a rotometer is used, the air mover should provide a constant volumetric flow rate (±20%) over the range of anticipated pressure drops. Relief valves or air inlets should be located downstream of the airflow measuring device (Corley et al. 1981). The direction of flow should be indicated on the collection device. Units powered by a portable generator or a self-contained battery have the advantage of allowing collection of a sample while the field team relocates to a low background radiation area. When using a sampler that runs off the car battery, the running engine may disturb air flow patterns. Therefore, the sampler needs to be positioned away from the disturbed air flow.

Sampling for airborne particulates requires the use of a filter media consistent with the sampling objectives (Klement 1982). For example, it may be desirable to collect alpha activity with a membrane filter for direct counting because of the excellent surface collection efficiency. However, the membrane filters are fragile and have relatively high pressure drops which require low flow rates. Flow rates need to be maintained relatively constant during sample collection. Polystyrene and glass fiber filters have been recommended for environmental applications (Corley et al. 1981). These filters have high collection efficiencies for particles in the respirable range and have a relatively low pressure drop that permits flow rates of many cubic feet per minute to be used. Filters and the holders are routinely located upstream of other sampling media such as charcoal cartridges. The filter holders should ensure an airtight seal around the perimeter of the filter and should have a porous, rigid backing material. Filters should be handled with forceps to minimize the potential for cross-contamination and to reduce the likelihood of dislodging the collected activity.

Common media for iodine sampling include particulate filters for collecting particulate iodines, and silver zeolite, silver-loading silica gel, or activated charcoal cartridges for collecting gaseous iodine. Collection efficiency of gaseous iodine is a function of several factors including the type of charcoal, packing density of granules, bed depth, size of the granules, flow rate, and the chemical species of iodine to be sampled (Corley et al. 1981; Kathren 1984). Commercially available cartridges are routinely used for iodine sampling. Flow rates should be optimized for maximum collection efficiency and minimal leakage of the adsorbed activity. Channeling can occur through the charcoal beds and reduce the collection efficiency. The charcoal cartridges should remain sealed before use to preclude extraneous adsorption of iodine or other gases. Similar considerations apply to silica gel cartridges used for tritium sampling (NCRP 1976; NCRP 1979).

If noble gases are also present, they will be collected along with the iodines on the charcoal. The silver zeolite and silica gel have a much lower collection efficiency for noble gases and would be the preferred collection media for iodine, when noble gases are present. However, good practice would be to purge the cartridge with clean air to remove any noble gases that may be collected prior to counting for iodines.

4.6 FIELD MEASUREMENT CONSIDERATIONS

Supervisory personnel need to consider several factors that could impact where field teams are deployed. Precipitation at the time of the release could result in the washout of radioactive material from the plume close to the release point. Whether the release is ground level or elevated would also impact the downwind ground deposition. For example, an accident involving a fire would produce an elevated release due to the buoyant force of the fire. In this situation, maximum ground deposition concentrations would occur at the location where the plume touches down.

The general rule in deploying field teams is to survey from less contaminated areas to more contaminated areas, locating any offsite contamination first. Field teams should first determine the boundaries of the contaminated area to restrict access to this area and to prevent the further spread of contamination or any unnecessary radiation exposure. After the boundaries have been determined, more detailed surveys can be conducted to better define the deposition pattern.

Portable survey instruments should be used to measure the deposited activity and provide information expeditiously. Good surveying practices include the following:

- Field teams should perform surveys in a consistent manner. They should try to hold the detector at a constant distance from the surface being surveyed. For example, when surveying for gamma-emitting radionuclides using a μR meter, the detector should be about 1 m from the surface. If surveying using a GM detector, the detector should be about 2.5 cm from the surface. Teams should also report readings that represent the average exposure rate value in an approximate 9.3-m^2 (100-ft^2) area.
- Field teams should be aware of natural sources of activity that may present elevated background levels near their facilities. These could include rock outcroppings and concrete buildings. A knowledge of the variations in naturally occurring radioactive materials would be useful in analysis and interpretation of the field data.

- Field teams should be cognizant of the need to collect smear samples in the affected area. Smear samples would provide an indication of surface contamination levels on smooth surfaces such as parked vehicles or building surfaces in the affected area. Typically, smears are taken over a 100 cm^2 area using filter paper to wipe the surface. Smears can be counted in the field using portable survey instruments or in the laboratory using gross counting techniques.

4.7 COORDINATION WITH OFFSITE AGENCIES

If the accident is severe enough, state and federal monitoring personnel will come to the scene to take samples. A facility's emergency environmental monitoring procedures should emphasize the importance of conducting a coordination meeting when outside groups arrive. Items such as the following should be discussed at the meetings:

- Maps and coordinate systems for locating sampling points - The facility should have enough maps to supply the state and federal support agencies so a common basis can be used for monitoring and sampling.

- Sample collection and analysis procedures - Efforts should be made to use common sample collection procedures. Counting and analysis procedures of all groups should be carefully reviewed to assure that there are no gross differences among the methods.

- Reporting of data in common units - All organizations performing sampling and analyses should report results in common units.

4.8 RECORDKEEPING

Good recordkeeping practices should be maintained from the onset of an emergency. Facility field teams should keep a detailed log of all air and environmental samples collected and exposure rate measurements taken. The log should include information such as location, time collected or measured, time air sample started and finished, and type of sample. Preprinted data sheets provide an excellent format and should be available in field team procedures for recording this information.

Recordkeeping also involves careful and complete labeling of the samples. Again, preprinted forms (labels) are recommended. The labels should contain information such as the team collecting the sample, sampling location, sample time (for an air sample this should include start time and stop time of sampler as well as initial and final flow rates), sample type, sample size (i.e., total volume of air sample or total area from which soil or vegetation sample was collected), and radiation level from the sample as measured by a portable survey instrument.

If an emergency is not severe enough to require federal assistance, the recordkeeping measures described in the above paragraphs should be sufficient to allow the facility to maintain control over the environmental samples being collected and analyzed. These recordkeeping measures should also be adequate if federal assistance is requested and a computerized data base is established. A data base has been developed for the DOE by EG&G to facilitate the organization and management of the environmental data collected during and after an accident (Berry and Burson 1987).

In an accident situation where FRMAP has been implemented and a FRMAC has been established, environmental samples collected by facility, state, and federal agency field teams would be entered into the data base operated by EG&G. Each organization collecting and analyzing samples will need guidance for labeling samples to ensure that an effective data base is maintained. As discussed in Berry and Burson (1987), the following information should be included in the computerized data base at the FRMAC:

- reference ID number assigned to each piece of original data received
- time and date the sample was collected or measurement was taken
- location where sample was collected or measurement was taken based on a common coordinate system
- identity of the organization that collected the sample
- identity of the organization that analyzed the sample
- sample collection ID number and laboratory analysis ID number
- type of sample (e.g., air, soil, or water) and type of analysis performed
- measurement or analytical results and units of measure
- any significant comments that may affect data assessment (e.g., rainfall during time sample was collected).

Figures 4.4 through 4.9 are forms that have been developed for the FRMAP of DOE Radiological Assistance Region 1 (DOE 1988) to aid in collecting, filing, and reporting of data at a FRMAC. These forms provide excellent examples of the type of information that facilities should document in an emergency. The following is a discussion of how each form could be used by a radioactive material facility in an emergency:

- Field Monitoring Data Log (Figure 4.4) - This form could be used by field teams to record all field radiation measurements, information on sample collection, specific locations, and team status. Certain portions of this form may not be applicable to all facilities because most facilities would not be performing field iodine air monitoring or scintillator measurements.

Page ________ of ________

Incident ________

Time Dispatched ________

Time Returned ________

Orig./Team ________

Date ________

Iodine Kit # ________

Or Serial #B ________

Ref. No. ________

NAMES

1. ________

2. ________

FIELD MONITORING DATA LOG

NOTE: REPORT ACTUAL BACKGROUND LEVEL OR MDL

		SCINTILLATOR Model ____ Serial NO ____ Units ____	GM Model ____ Serial No. ____ Units ____			ION CHAMBER Model ____ Serial No. ____ Units ____	FIELD IODINE AIR MONITORING ____ CFM/ ____ Min. Sample			SAMPLE COLLECTION			SMEAR	
TIME	LOCATION Grid Co-ordinates, Crossroads, etc.	Meter Reading	Meter Reading	Beta Window Open Closed	Height 4 in. 3 ft.	Meter Reading	Background (CPM)	Gross CPM with Particulate Filter	Gross CPM without Particulate Filter	Tag No.	Type: Soil, Milk, Water	Quantity and Units	CPM Per 100 CM² Unless Noted	COMMENTS (Indicate Factors Such As Peak Reading, Cloud Passage, Instrument and Weather Conditions, and Other Data)

FIGURE 4.4. Field Monitoring Data Log Form

FIELD MONITORING TEAM
COMMUNICATION LOG

INCIDENT ______________ PAGE ____ OF ____

TEAM ______________________ DATE ______________________

TEAM MEMBERS ______________________ TIME OUT ______________________

ORGANIZATION ______________________ TIME IN ______________________

TIME	FROM	TO	COMMUNICATION

FIGURE 4.5. Field Monitoring Team Communication Log Form

Ref. No. 22[illegible]

SAMPLE TAG

FIELD TEAM USE	TAG NO.
Organization ______	
Team ______	

Sampling Location ______
(Be Specific, Grid Coordinates, etc.)

Date/Time Collected ______ ______

Radiation Level ______ mR/Hr Contact

Sample Type ______

Sample Size ______
(Volume/Area)

Comments ______

______

______

SAMPLE ANALYSIS COORDINATOR

Analyze For ______ Lab ID ______

Gamma ______ Gross Alpha ______

Tritium ______ Gross Beta ______

Other ______

Priority: 1. ______ Emergency

2. ______ Urgent

3. ______ Routine

Laboratory/Location ______

Lab Manager ______ Phone (   ) ______

White – Sample Analysis Coordinator   Canary – Laboratory   Pink – Data Evaluation

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FIGURE 4.6. Sample Tag Form

Ref No ________

Page ____ of ____

LABORATORY ANALYSIS REPORT

Incident ____________

Laboratory ____________
Lab Manager ____________
Sample Tag No ____________
Lab Sample No ____________

Sample Type ____________
Collector ____________
Location ____________
Date/Time of Sampling ____________

Analysis Type ____________
Analysis Date/Time ____________
Instrument ____________
Serial No. ____________

COMPLETE FOR AIR SAMPLES

Date/Time On ________ Date/Time Off ________
Flow Rate ________ Flow Rate ________
Volume ________

Radiation Level ________ mR/hr Contact
Total Sample Size ________
Amount Analyzed ________

Nuclide	Activity (At Time of Sampling)	Error	Units	Minimum Detection Activity	Counting Time	Comments

Report Prepared By ____________
Analyst ____________
SA Coordinator ____________

Route To: ____________

FIGURE 4.7. Laboratory Analysis Report Form

LABORATORY SAMPLE LOG

INCIDENT ______________________ PAGE ____ OF ____

LABORATORY ______________________

LAB MANAGER ______________________

RECEIVED		TAG NUMBER	COLLECTED		LAB ID	PRIORITY	SAMPLE DESCRIPTION	ANALYSIS	TOTAL VOLUME	ALIQUOT ANALYZED	ANALYZED BY	COMPLETED
DATE	TIME		DATE	TIME								

FIGURE 4.8. Laboratory Sample Log Form

SAMPLE STORAGE

	RECEIVED FOR SAMPLE STORAGE					SAMPLE INFORMATION			RELEASED FROM SAMPLE STORAGE				
TAG NO.	ORGANIZATION (FROM)	RELEASED BY (SIGN)	DATE	TIME	RELEASED BY	TYPE	QUANTITY (BE SPECIFIC)	RADIATION LEVEL UNITS _____	ORGANIZATION (TO)	RECEIVED BY (SIGN)	DATE	TIME	RELEASED BY

FIGURE 4.9. Sample Storage Form

- Field Monitoring Team Communication Log (Figure 4.5) - This log could be used by the field teams and supervisory personnel controlling the teams to record any communications.

- Sample Tag (Figure 4.6) - This tag could be attached to each sample collected in the field. The top portion would be completed by the field team. Under the heading entitled "Radiation Level," information on the type, serial number, and calibration date of the instrument used to record the radiation level should also be included. The bottom portion would be completed by supervisory personnel when the sample is returned from the field and would serve to route the sample to an appropriate laboratory or counting facility for analysis. This portion of the form should also have an entry for agricultural clearance if samples are to be sent to an offsite laboratory for analysis. Agricultural clearance may be required for samples collected in adverse agricultural locations where milk, soil, and vegetation may be carriers of agricultural pests. The danger would be to possibly infect another area (e.g., area where analytical laboratory is located).

- Laboratory Analysis Report (Figure 4.7) - The results of laboratory analysis could be recorded on this form, one form for each sample. The form should also have an entry for sample disposition.

- Laboratory Sample Log (Figure 4.8) - The laboratory or counting room supervisor would be responsible for maintaining this log which is a running list of all samples analyzed.

- Sample Storage (Figure 4.9) - This form could be used by facilities to log samples into a storage area after they are analyzed and to log out samples that require additional analysis or reanalysis.

4.9 QUALITY ASSURANCE

A quality assurance (QA) program should ensure that emergency environmental equipment and supplies are maintained and periodically inventoried. Radiation detection equipment used in field team kits need to have current calibrations. When calibrations are due, a good practice is to rotate instruments in field team kits with the facility's routinely used instrument supply. Kits should be inventoried annually to ensure that all supplies are available should the kits be needed in an emergency. A member of the facility's emergency preparedness or health physics staff should be responsible for kit inventories and maintenance of emergency equipment. The facility's QA group should audit this function annually.

Regulatory Guide 4.15 (NRC 1979) describes elements that should be included in a QA program for effluent and environmental measurements at nuclear facilities during normal operations. Many of the elements are applicable to both routine operations and accident situations. The following elements from Regulatory Guide 4.15 have a direct bearing on the reliability of environmental measurements made during and after a radiological accident.

- Adequate records must be kept to document the actions from sample collection through evaluation of the analytical data. In addition to the items discussed in Section 4.8, laboratory notebooks should be used to describe sample preparation including the radiochemical and analytical procedures used. Background counts, source check counts, QC sample results, energy calibrations, and energy resolutions should be evaluated and recorded to ensure that the counting instrumentation is functioning properly. Review and verification of the analytical results should also be documented.

- A facility's analytical methods must be able to reproduce measurements within acceptable limits. Counting equipment performance needs to be evaluated using reference sources and by conducting background counts. Reference sources should be counted daily as a check on instrument stability (Inhorn 1978). Inhorn recommends that when a divergent trend develops or more than 5% of the counts fall outside two standard deviations of the average count rate, the cause should be investigated and corrected. Similar to the reference source counts, background counts need to be performed frequently to ensure levels are within an acceptable range. If not, the cause of the discrepancy (e.g., detector contamination) should be identified and corrected.

- Quality control samples need to be analyzed as part of an emergency environmental QA program. Blind duplicate samples should be evaluated as an internal precision check on the facility's analytical procedures (Inhorn 1978). This check involves analyzing duplicate aliquots of randomly selected samples. Laboratory personnel should not know which samples are duplicate (QC) samples. The duplicate samples should not be analyzed in the same batch as the original samples. Statistical methods for evaluating the acceptability of duplicate sample results can be found in Inhorn (1978), Youden and Steiner (1975), and Wernimont (1987).

- During routine operations, 5 to 10% of the sample workload should consist of QC samples (NRC 1979). Five percent may be practical in the initial and intermediate phases of an emergency when sample turnaround time is crucial for determining the magnitude of a release. However, in the recovery phase when time is not so critical, 10% of the total sample workload should be QC samples. When more than one analytical laboratory is involved, QC samples should also be used for interlaboratory comparisons.

- Methods for investigating out of tolerance values (e.g., reference source counts, background counts, QC samples) should be a part of the QA program. Corrective actions taken as a result of the investigation should be documented.

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APPENDIX A

FEDERAL GUIDANCE ON PROTECTIVE ACTIONS

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The Environmental Protection Agency (EPA) provides protective action guides (PAGs) for whole body exposure and thyroid dose from a passing radioactive plume (EPA 1980). For the general population, PAGs are 1 to 5 rem to the whole body and 5 to 25 rem to the thyroid. PAGs for emergency workers are 25 rem to the whole body and 125 rem to the thyroid. EPA guidance recommends sheltering the public if projected whole body dose is between 1 and 5 rem or if projected thyroid dose is between 5 to 25 rem. Evacuation is recommended if projected whole body dose is greater than 5 rem or if projected thyroid dose is greater than 25 rem.

The Food and Drug Administration (Fed. Reg. 1982) provides guidance on protective actions for accidental radioactive contamination of human food and animal feeds. The guidance identifies two grades of PAGs which are described below:

- Preventive PAG - situation where contamination is projected to result in 1.5 rem dose commitment to the thyroid or 0.5 rem dose commitment to the whole body, bone marrow, or other organs. Table A.1 provides derived response levels for initial deposition, forage concentration, and milk which would be equivalent to the dose commitment level mentioned above. These response levels were calculated for infants (critical segment of the population) and are provided for five radionuclides: ^{131}I, ^{134}Cs, ^{137}Cs, ^{89}Sr, and ^{90}Sr. Responsible officials should take protective actions at these response levels to prevent or reduce the concentration of radioactivity in food or animal feed. An example of a typical protective action is to remove cows from contaminated pastures and substitute stored feed and water.

- Emergency PAG - situation where contamination is projected to result in 15 rem dose commitment to the thyroid or 5 rem dose commitment to the whole body, bone marrow, or other organs. Table A.2 provides derived response levels from the FDA guidance for initial deposition, forage concentration, and milk which would be equivalent to the dose commitment level mentioned above. Response levels were derived for both infant and adult for the same five radionuclides as those for the Preventive PAGs. The Emergency PAGs are a factor of 10 greater than the Preventive PAGs. At these response levels, responsible officials should isolate food containing radioactive materials to prevent its introduction into the food chain.

TABLE A.1. Derived Preventive Response Levels for Human Food and Animal Feeds[a,b]

	^{131}I(c)	^{134}Cs(d)	^{137}Cs(d)	^{89}Sr	^{90}Sr
Initial Deposition (microcurie/square meter)	0.13	2	3	8	0.5
Forage Concentration (microcurie/kilogram)[e]	0.05	0.8	1.3	3	0.18
Peak Activity: Milk (microcurie/liter)	0.015	0.15	0.24	0.14	0.009
Total Intake[f] (microcurie)	0.09	4	7	2.6	0.2

(a) FDA Recommendation, October 22, 1982, Federal Register, Vol. 47, 47 FR 47073.
(b) Newborn infant includes fetus (pregnant women) as critical segment of population for ^{131}I. For other radionuclides, "infant" refers to child less than 1 year of age.
(c) From fallout, ^{131}I is the only radioiodine of significance beyond the first day with respect to milk contamination. In case of a reactor accident, the cumulative intake of ^{133}I via milk is about 2.0% of the ^{131}I assuming equivalent deposition.
(d) Intake of cesium via the meat/person pathways for adults may exceed that of the milk pathway. Therefore, such levels in milk should cause surveillance and protective actions for meat as appropriate. If both ^{134}Cs and ^{137}Cs are equally present, as might be expected for reactor accidents, the levels should be reduced by a factor of 2.
(e) Fresh weight.
(f) Integrates total ingestion from a single contaminating event.

No formalized federal guidance currently exists for water and the non-dairy food pathway. The Federal Emergency Management Agency (FEMA) is developing this guidance. Draft guidance can be found in Salmonson et al. (1984). Derived preventive response levels for vegetable foodstuffs are provided in Table A.3 for ^{131}I and ^{137}Cs. The response levels for the child, teen, and adult are based on 1.5 rem to the thyroid and 0.5 rem to the whole body, bone marrow, or other organs. Derived preventive response levels for drinking water are found in Table A.4 for ^{131}I, ^{134}Cs, ^{137}Cs, ^{89}Sr, and ^{90}Sr. Response levels are given for an infant, child, teenager, and adult.

TABLE A.2. Derived Emergency Response Levels for Human Food and Animal Feeds[a]

	^{131}I		^{134}Cs		^{137}Cs		^{89}Sr		^{90}Sr	
	Infant[b]	Adult	Infant[c]	Adult[d]	Infant	Adult	Infant	Adult	Infant	Adult
Initial deposition (microcurie/square meter)	1.3	18	20	40	30	50	80	1600	5	20
Forage Concentration Pasture (microcurie/kilogram)[e]	0.5	7	8	17	13	19	30	700	1.8	8
Peak Activity: Milk (microcurie/liter)	0.15	2	1.5	3	2.4	4	1.4	30	0.09	0.4
Total Intake[f] (microcurie)	0.9	10	40	70	70	80	26	400	2	7

(a) FDA Recommendation, October 22, 1982, Federal Register, Vol. 47, 47 FR 47073.
(b) Newborn infant includes fetus (pregnant woman) as critical segment of population for ^{131}I.
(c) For cesium and strontium, "infant" refers to a child less than 1 year old.
(d) Intake of cesium via the meat/person pathways for adults may exceed that of the milk pathway. Therefore such levels in milk should cause surveillance and protective actions for meat as appropriate. If both ^{134}Cs and ^{137}Cs are equally present, as might be expected for reactor accidents, the levels should be reduced by a factor of 2.
(e) Fresh weight.
(f) Integrates total ingestion from a single contaminating event.

TABLE A.3. Derived Preventive Response Levels for Vegetable Foodstuffs[a]

Population Sector	Leafy Vegetable[b] µCi/kg		Produce (non-leafy vegetable, fruits, and grains)[c]	
	^{131}I	^{137}Cs	^{131}I	^{137}Cs
Child	0.55	1.1	0.043	0.003
Teen	0.77	1.4	0.085	0.0054
Adult	0.82	2.3	0.016	0.016

(a) Taken from Salmonson (1984).
(b) Assumes a leafy vegetable ingestion period equivalent to the radionuclide mean effective lifetime (7.3 days for ^{131}I and 20 days for cesium) and daily ingestion rates of 0.07, 0.12 and 0.18 kg/day for the child, teenager, and adult, respectively.
(c) Assumes a produce ingestion period equivalent to 11.5 days for ^{131}I and 365 days for ^{137}Cs. Ingestion rates are 1.42, 1.73, and 1.42 kg/day for the child, teenager, and adult, respectively.

TABLE A.4. Derived Preventive Response Levels for Drinking Water[a]

Population Group	Nuclide Concentration in Water (µCi/L) Equivalent to PAG Ingestion Dose Commitment[b]				
	^{131}I	^{134}Cs	^{137}Cs	^{89}Sr	^{90}Sr
Infant	0.024	0.16	0.18	0.044	0.060
Child	0.037	0.19	0.22	0.054	0.0042
Teenager	0.09	0.36	0.48	0.16	0.0086
Adult	0.10	0.74	0.82	4.2	0.071

(a) Taken from Salmonson (1984).
(b) For ^{131}I, critical organ is thyroid; for cesium, critical organ is liver; and for strontium, critical organ is whole body.

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APPENDIX B

FIELD SURVEY TECHNIQUES

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FIELD SURVEY TECHNIQUES

Field teams must be able to accurately document the positions where radiation measurements and environmental samples have been taken. Without this information, the data that is obtained is much less valuable. Grid patterns are commonly used to assure a systematic approach for locating environmental measurements and samples. Two types of grid patterns are useful in emergency situations because of their simplicity. These are the radial and rectangular grids and each type is discussed below with respect to its use in the field and its limitations. In addition, methods to measure survey distances and to use a compass to map an area are described.

To establish a survey grid, a central reference point is located as the basis for the other survey points. The exact location of the central reference point must be known. It will usually be the location of the radioactive material facility. Compass headings will be taken from the central reference point to establish the survey grid. Distinctive landmarks along compass headings may be helpful as additional reference points. Examples of radial and rectangular grids are shown in Figures B.1 and B.2, respectively.

The radial grid is commonly used to make a rapid determination of the extent and magnitude of the contamination levels in the field. As the distance from the central reference point increases, so does the distance between the radials (see Figure B.1). If the radials are spaced too far apart, it is possible that a contaminated area would not be detected. For this reason, the number of radials selected should be sufficient to minimize the possibility of missing a contaminated area. Radial grids would be most useful for surveying relatively small areas and areas that are close to the source of the release.

Survey teams should proceed from less contaminated areas to the higher contaminated area when performing initial surveys using a radial grid. This could involve moving inward from the boundaries of the contaminated area during the survey. The numbered locations in Figure B.1 are referenced by the bearing and distance along the radial. For example, point 1 is 500 ft from the central reference point at a bearing of 270 degrees, and point 14 is 1000 ft from the central reference point at a bearing of 330 degrees.

Rectangular grids can be used for a more detailed survey that will further refine the field measurements already made using a radial grid. These surveys are more labor intensive and generally require more time to complete than a radial survey. Rectangular grids would be used primarily during the intermediate and recovery phases following an accident. From a central reference point, two perpendicular compass headings are established with reference points located at specified distances determined by the size of the contaminated area (see Figure B.2). The rectangular grid shown in Figure B.2 is labeled with an alpha-numeric coordinate system.

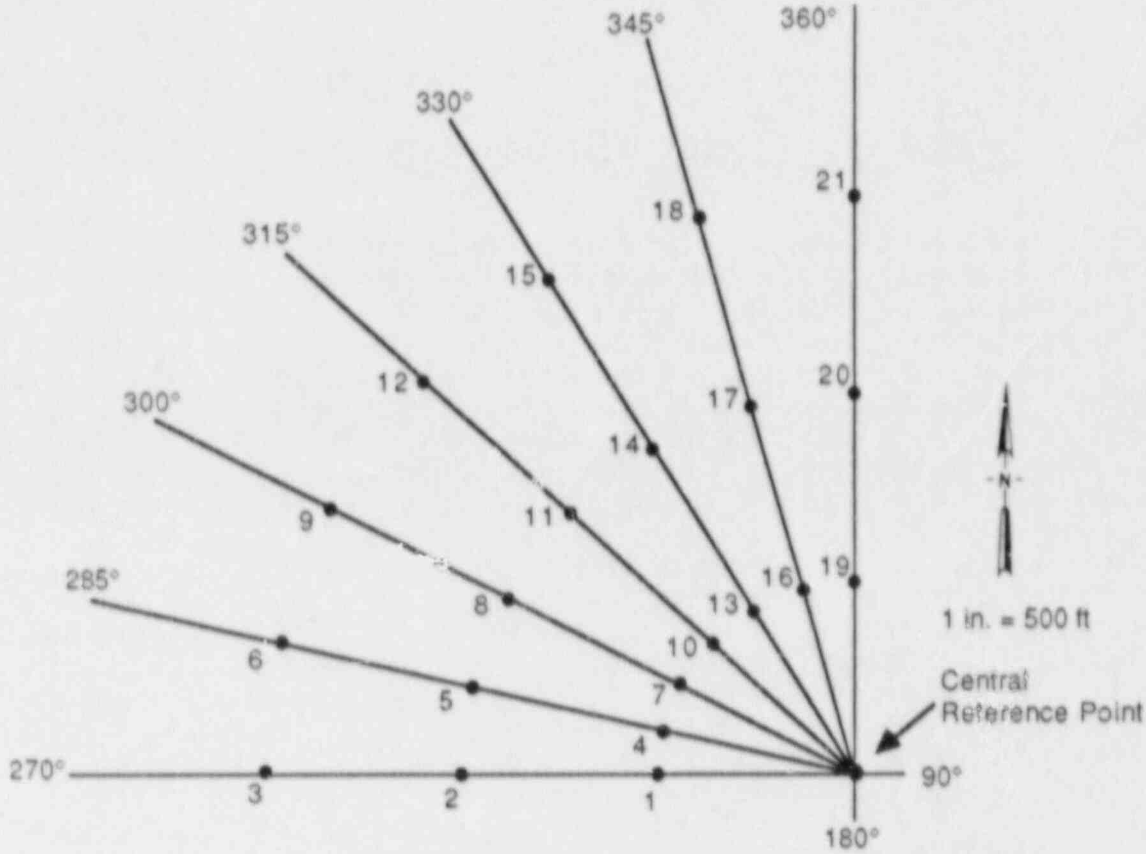

FIGURE B.1. Radial Survey Grid

The compass is an essential piece of equipment to accurately map an area being surveyed by a field team. A compass is graduated into 360 degrees where north is both 0 and 360 degrees, east is 90 degrees, south is 180 degrees and west is 270 degrees. The compass needle points to magnetic north. The angle this magnetic north line makes with a line pointing to true north is known as the angle of declination. The angle of declination varies in different parts of the country. If the survey lines are to be referenced to true north, then the compass reading must be corrected by the angle of declination. Alternatively, the needle of the compass can be adjusted to true north before the survey.

Survey distances can be measured using a tape measure or by pacing. Pacing is quicker but less accurate. However, for emergency field surveys on relatively flat terrain, pacing should be adequate. Distance is measured by counting the number of steps and multiplying by the length of each step. A single foot (e.g., left) can be used to count the steps. Thus, the pace is the mean distance covered in two steps.

Locations in the survey area may need to be identified at a later time. Stakes and cans of spray paint are adequate for this identification during the initial, intermediate, and recovery phases when referenced to the central

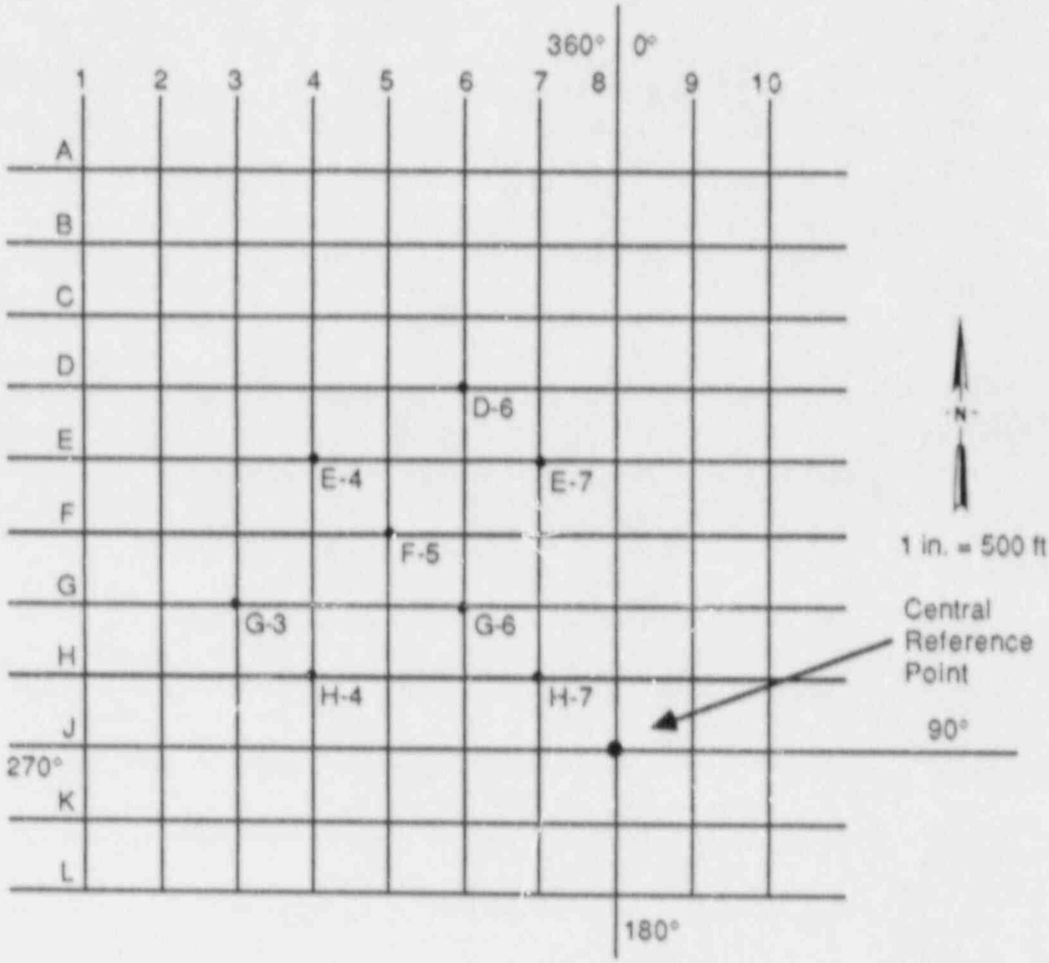

FIGURE B.2. Rectangular Survey Grid

reference point. However, they can be easily altered by unauthorized persons. In the intermediate and recovery phases when more time is available, photographs can be easily made of the affected area with the locations marked.

The survey map should be drawn to scale. For example, over relatively small areas, a scale of 1 in. on the map to 500 ft on the ground could be used. The readings taken and the locations of the readings must be clearly recorded. Areas where the dose rates or contamination levels change should be noted and recorded. The maximum readings obtained during the survey should also be recorded.

Topographical features such as rugged terrain, swamps, rivers, and lakes can make it difficult to use radial or rectangular grids. A survey traverse can be used in these cases. The traverse is connected by a series of survey lines. Each line is determined by its bearing and distance, beginning at a selected point. Beginning at point A, a compass heading is taken on point B and recorded. The distance between A and B is measured or paced and recorded. From point B, a compass heading is taken on point C and recorded. The distance between B and C is determined and recorded. The survey progresses in this manner until completed. Accurate and complete notes must be taken so a useful map can be drawn and the data can be interpreted.

APPENDIX C

EMERGENCY MONITORING EQUIPMENT

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EMERGENCY MONITORING EQUIPMENT

RADIATION DETECTION INSTRUMENTATION

- Portable survey instruments - GM, ionization chambers, NaI, portable alpha monitors
- Check sources
- Self-reading dosimeters with charger/reader
- Portable counting system - NaI, proportional counting system.

AIR SAMPLING EQUIPMENT

- High- or low-volume air samplers with appropriate power supplies (e.g., portable electric generator, vehicle battery, or AC/DC inverter)
- Filter paper, charcoal, or silver zeolite cartridges.

PROTECTIVE CLOTHING

- Coveralls
- Cotton gloves
- Rubber gloves
- Rubber shoe covers.

MISCELLANEOUS

- Adhesive labels
- Tape (masking and radiation warning)
- Pens and pencils
- Clipboards
- Procedures including maps
- Kit Inventory Checklist
- Coins
- Stop watch
- Battery cables
- Extension cord (heavy duty)
- Flashlights with extra batteries
- Calculator
- Keys to any gates which may prevent access to roads near the facility
- Screwdriver/pliers
- Tweezers
- Decontamination solution

- Compass
- Rags/paper towels
- Knife/scissors
- First Aid kit.

GENERAL SAMPLING EQUIPMENT

- Sample Containers - plastic jugs, ziplock plastic bags (several sizes), envelopes, large trash bags
- Pruner
- Trowel
- Clippers
- Tape measure/yardstick
- Funnel
- Shovel
- Bucket
- Scoop.

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This report provides information that could be used by radioactive material facilities for developing or improving environmental sampling and analysis programs for emergency conditions. Areas that need to be addressed during the planning phase of such a program include 1) emergency organization, 2) sample measurement and collection locations, 3) required equipment and supplies, 4) sample collection procedures, 5) field measurement methods, 6) recordkeeping methods, and 7) quality assurance program. Emphasis is placed on the need for these facilities to coordinate monitoring activities with any supporting agencies, such as state and federal monitoring teams who might respond. The report also reviews the responsibilities and current capabilities of radioactive material facilities, state and local government agencies, and federal agencies with regard to environmental sampling and analysis in an emergency situation.

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