Chapter 4
Steps in Planning for the Acquisition of Useable Environmental Data

This chapter provides guidance to the RPM and the risk assessor for designing an effective sampling plan and selecting suitable analytical methods to collect environmental data for use in baseline risk assessments. Part A, Chapter 4 contains worksheets that can be used to assist the risk assessor or RPM in designing an effective sampling plan and selecting the proper analytical methods.

4.1 STRATEGIES FOR DESIGNING SAMPLING PLANS

The discussion in Part A, Section 4.1 regarding sample location, size, type, and frequency applies to radioactively contaminated sites as well. However, the resolution and sensitivity of radioanalytical techniques permit detection in the environment of most radionuclides at levels that are well below those that are considered potentially harmful, while analytical techniques for nonradioactive chemicals are usually not this sensitive. For radionuclides, continuous monitoring of the site environment is important, in addition to the sampling and monitoring programs described in Part A, Section 4.1. Many field devices that measure external gamma radiation, such as high pressure ionization chambers, provide a real time continuous record of radiation exposure levels. Such devices are useful for determining the temporal variation of radiation levels at a contaminated site and for comparing these results to the variability observed at background locations. Continuous measurements provide an added level of resolution for quantifying and characterizing radiological risk.

Additional factors that affect the frequency of sampling for radionuclides include the half-lives and the decay products of the radionuclides. Radionuclides with short half-lives, such as I-131 (half-life = 8.04 days), have to be sampled more frequently because relatively high levels of contamination can be missed between longer sampling intervals. The decay products of the radionuclides must also be considered, because their presence can interfere with the detection of the parent nuclides of interest, and because they also may be important contributors to risks.

The Sampling Design Selection Worksheet shown in Exhibit 5 may be used to assist in the design selection for the most complex environmental situation, which is usually soil sampling. This worksheet is similar to the worksheet found in Part A, Exhibit 45. Directions for filling out the worksheet can be found in Part A, Section 4.1.2. The worksheet should be completed for each medium and exposure pathway at the site. Once completed, this initial set of worksheets can be modified to assess alternative sampling strategies.

There are two details to keep in mind while filling out the worksheet:

- Providing expedited sampling and analysis when radionuclides with short half-lives are a concern.
- Increasing reliance on field survey data in all aspects of planning, since field data often provide easy identification of many radionuclides and guide sample collection.

Since field duplicates and blanks are such an important determinant of measurement error precision, careful attention must be paid to the number that are collected. Part A, Exhibit 48 provides the number of duplicate pairs of QC samples required to obtain a specific confidence level.

4.1.1 Determining the Number of Samples

An important aspect in designing a sampling plan is the number of samples required to fully characterize each of the three exposure pathways. Several methods for

Acronyms

CLP	Contract Laboratory Program
DQO	data quality objective
EMSL/LV	Environmental Monitoring Systems Laboratory/Las Vegas
NAREL	National Air and Radiation Environmental Laboratory
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NIST	National Institute of Standards and Technology
ORP/LVF	Office of Radiation Programs/Las Vegas Facility
PRP	potentially responsible party
QA	quality assurance
QAP	Quality Assurance Program
QC	quality control
RPM	remedial project manager
SAP	sampling and analysis plan
SDWA	Safe Drinking Water Act
USNRC	U.S. Nuclear Regulatory Commission

EXHIBIT 5. HIERARCHICAL STRUCTURE OF SAMPLING DESIGN SELECTION WORKSHEET

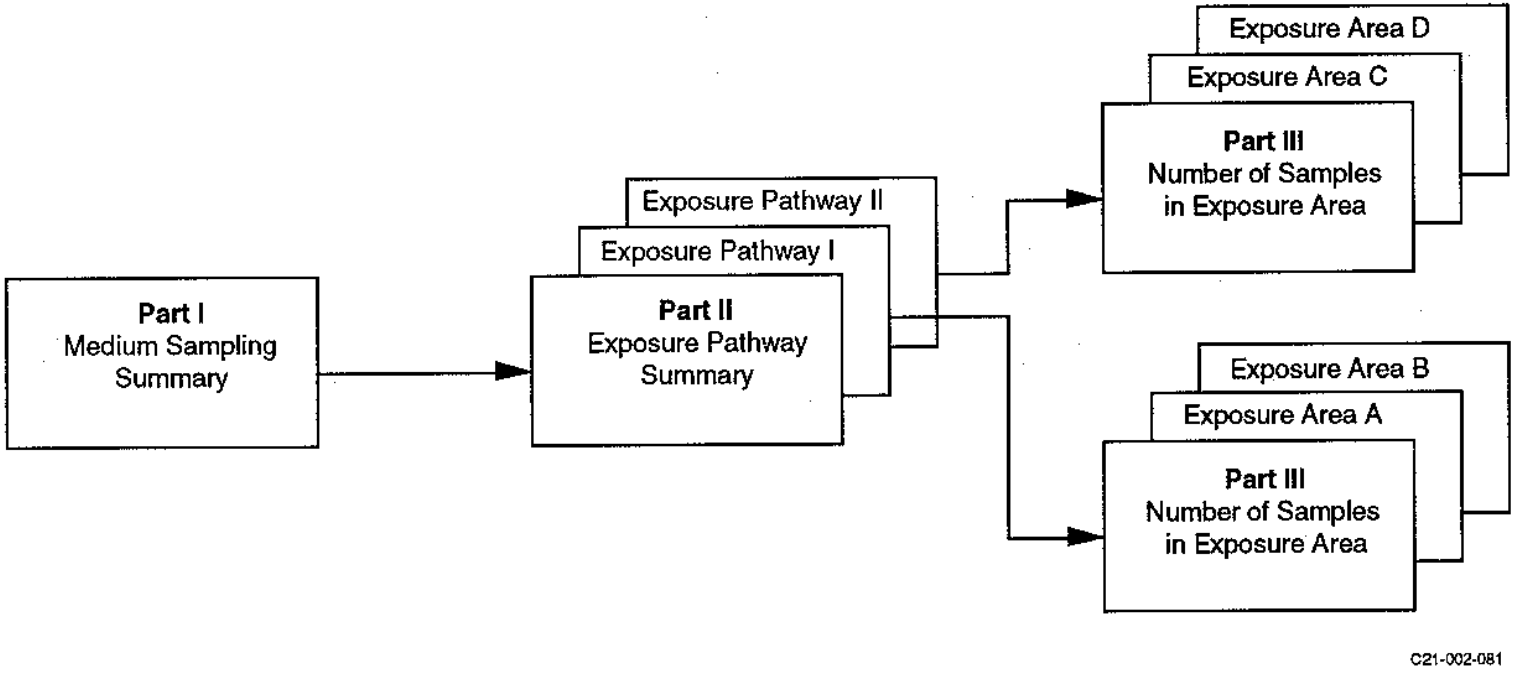

EXHIBIT 5. PART I: MEDIUM SAMPLING SUMMARY SAMPLING DESIGN SELECTION WORKSHEET (Cont'd)

A. Site Name _____ B. Base Map Code _____

C. Medium: Groundwater, Soil, Sediment, Surface Water, Air

Other (Specify) _____

D. Comments: _____

E. Medium/ Pathway Code	Exposure Pathway/ Exposure Area Name	F. Number of Samples from Part II					
		Judgmental/ Purposive	Back-ground	Statistical Design	Geo-metrical or Geo-statistical Design	QC	Row Total
	Column Totals:						
						G: Grand Total:	

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EXHIBIT 5. PART II: EXPOSURE PATHWAY SUMMARY SAMPLING DESIGN SELECTION WORKSHEET (Cont'd)

H. Radionuclide of Potential Concern and CAS Number	I. Frequency of Occurrence	J. Estimation		K. CV	L. Background
		Arithmetic Mean	Maximum		

M. Code (CAS Number) of Radionuclide of Potential Concern Selected as Proxy _____

N. Reason for Defining New Stratum or Domain (Circle one)

1. Heterogeneous Radionuclide Distribution
2. Geological Stratum Controls
3. Historical Information Indicates Difference
4. Field Screening Indicates Difference
5. Exposure Variations
6. Other (specify) _____

O. Stratum or Exposure Area	P. Reason	Q. Number of Samples from Part III					
Name and Code		Judgmental/ Purposive	Back-ground	Statistical Design	Geo-metrical or Geo-statistical Design	QC	Row Total
	R. Total (Part I, Step F):						

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EXHIBIT 5. PART III: EXPOSURE AREA SUMMARY SAMPLING DESIGN SELECTION WORKSHEET (Cont'd)

O. Stratum or Exposure Area _____ Domain Code _____
E. Medium/Pathway Code _____ Pathway Code _____

S. Judgmental or Purposive Sampling
Comments: _____
_____

Use prior site information to place samples, or determine location and extent of contamination. Judgmental or purposive samples generally cannot be used to replace statistically located samples.

An exposure area and stratum MUST be sampled by at least TWO samples.

Number of Samples

T. Background Samples
Background samples must be taken for each medium relevant to each stratum/area. Zero background samples are not acceptable. See the discussion on pp. 74-75 of Guidance for Data Useability in Risk Assessment Part A.

Number of Background Samples

U. Statistical Samples
CV of proxy or radionuclidel of potential concern _____
Minimum Detectable Relative Difference (MDRD) _____ (<40% if no other information exists)
Confidence Level _____ (>80%) Power of Test _____ (>90%)

Number of Samples
(See formula in Appendix IV)

V. Geometrical Samples
Hot spot radius _____ (Enter distance units) _____
Probability of hot spot prior to investigation _____ (0 to 100%)
Probability that NO hot spot exists after investigation _____ (enter only if >75%)
(see formula in Appendix IV)

W. Geostatistical Samples

Required number of samples to complete grid +
Number of short range samples

X. Quality Control Samples
Number of Duplicates (Minimum 1:20 environmental samples) _____
Number of Blanks (Minimum 1 per medium per day or 1 per sampling process, whichever is greater) _____

Y. Sample Total for Stratum
(Part II, Step U)

Judgmental/ Purposive	Back-ground	Statis-tical Design	Geo-metrical or Geo-statistical	QC	Row Total

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determining the required number of samples are available, including the method discussed in Part A, Chapter 4 and Part A, Appendix IV. Alternative methods have been proposed by Schaeffer, et. al. (Schaeffer 1979) and Walpole and Meyers (Walpole 1978).

Each of the three exposure pathways from different sample media present separate problems in designing a sampling plan. A full discussion of sampling problems is beyond the scope of this guidance. A brief discussion of sampling soil, groundwater, and air pathways is included as an example for a typical 10-acre site. The number of samples and sampling locations listed are the minimum number of samples required, and these numbers will increase for most applications. The area of consideration, the time available for monitoring, the potential concentration levels of the contaminants, and the funding available all influence the number of samples to be analyzed.

Measurements of external exposure from soil are taken with portable instruments as described in Section 3.2, usually at 1 meter above ground level. The initial measurements will be performed at predetermined grid intersections, typically at intervals of 50 feet or 20 meters. This spacing produces about 20 to 25 measurements per acre. Larger spacing could be used when surveying larger areas, especially if the contamination is expected to be widespread and evenly distributed at a constant depth below the surface. Conversely, the distance between measurements would decrease if the initial readings indicate contamination that is localized or particularly elevated relative to background. The primary objective in both cases is to collect enough data to determine the locations of maximum gamma radiation and to indicate zones of equal intensity (i.e., isopleths) around these points. This results in the familiar "bullseye" drawings indicating areas of suspected maximum contamination. Gamma exposure data are essential in selecting the locations for soil sampling and borehole surveys. For a typical 10-acre site, upwards of 250 radiation measurements will be required. These data are normally superimposed on a map or figure for ease of interpretation. The data should indicate where background readings were obtained for all sides of the site. Sources of radium activity will decay to radon gas. The radon gas is more mobile and can travel under the ground to give elevated surface readings where there is no source of radioactivity. When the radium source is removed the radon sources disappear. In these situations borehole surveys and a qualified health physicist or radiochemist can be used to help interpret the data.

Borehole surveys involve the use of a gamma-sensitive probe which is lowered into drilled or driven holes as described previously. Measurements of gamma count rate are made at predetermined depth intervals, typically every 6 inches. A site investigation may produce 100 or more borehole surveys. Depths of each hole will normally extend at least 1 foot beyond the bottom of the contaminated layer. When grade levels are approximately equal, boreholes normally terminate at the same depth. Therefore, boreholes showing no evidence of contamination should have penetrated to at least the same depth as those showing contamination. Practically speaking, borehole depths vary across a site as a function of the site characteristics and the sampling equipment used.

Exhibit 6 illustrates the need for borehole measurements. Surface surveys cannot detect contamination occurring at a great depth. Overlying soil cover which shields the radioactivity may produce a greatly reduced response at the surface. Depth profiles also provide a means for selecting soil sampling locations and are useful in prioritizing radiochemical analyses. This information can also be used to correlate data for non-gamma-emitting radionuclides to field surface radiation measurements.

Both surface soil composites and core samples from a subset of the locations selected by borehole profiling should be collected. Subsurface soil cores should be collected from 10 to 20% of the boreholes at a minimum of approximately 12 locations. The distribution of soil sample locations should be as follows:

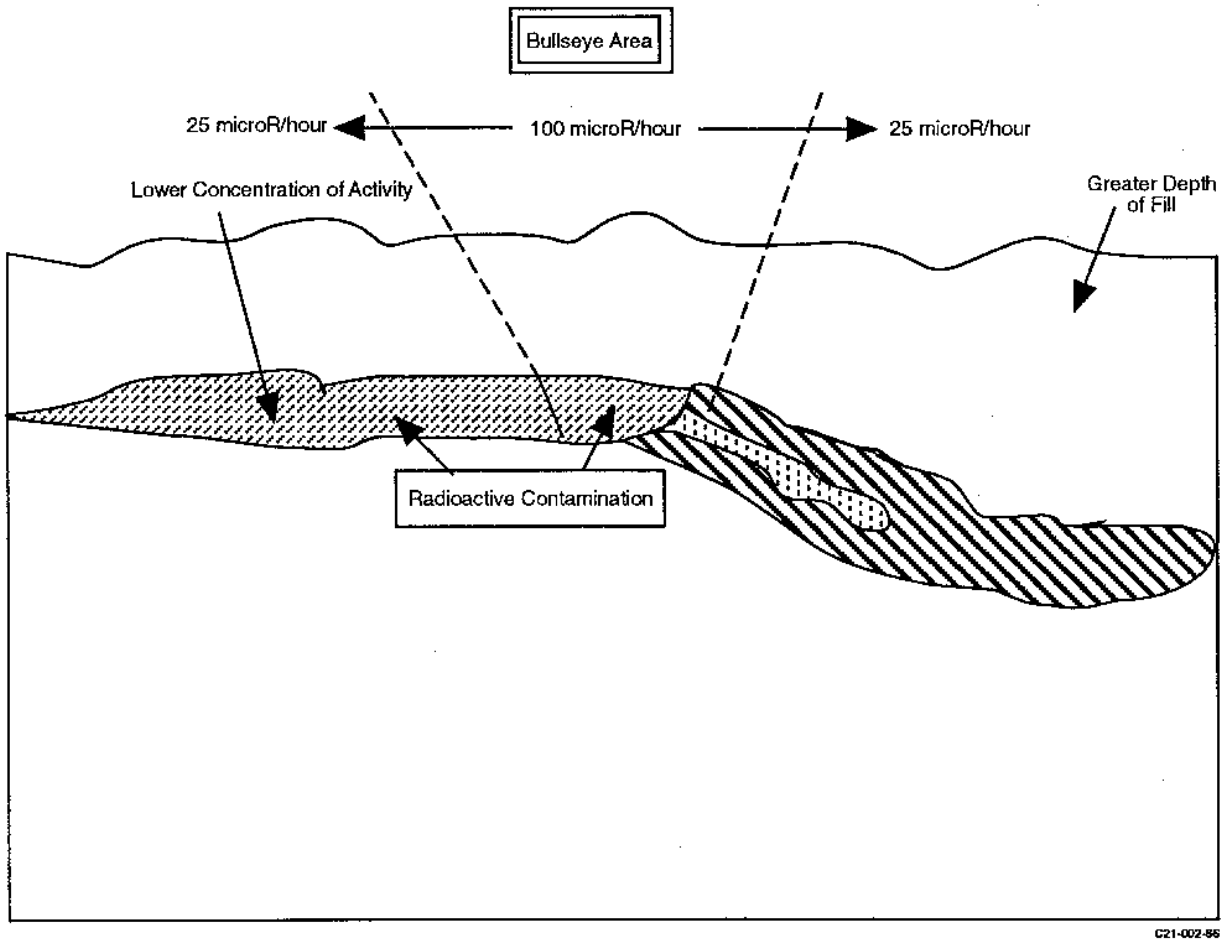
- Three from background locations.
- Three from hot spot ("bullseye") locations identified in the surface radiation survey.
- Three from locations defining the limits of the hot spots.
- Three defining the fringes or boundaries of the contaminated zone.

Soil cores are normally split into 6-inch increments. These cores can also be combined and analyzed as a composite, when resources are of critical importance. Borehole samples are taken to provide information concerning the extent of the contamination as well as the depth of the contamination.

Compositing of borehole samples can result in misinterpretation of the results when contamination varies with depth across the area being investigated.

Groundwater samples should be taken from a minimum of four locations: two background and two indicator locations. If the sampling locations were chosen in the absence of knowledge of the groundwater flow patterns,

EXHIBIT 6. EFFECT OF SOURCE DEPTH ON SURFACE GAMMA RADIATION MEASUREMENTS



close inspection of comparative data is required to ensure that background samples are not potentially contaminated. Without knowledge of the groundwater flow, background samples may be collected on opposite sides of the site. If the groundwater flow is perpendicular to the line between these two locations, both are likely to be true backgrounds. If the flow is parallel to this line, one or the other may be contaminated. Contamination of both "background" samples may suggest local flow reversal or contamination from sources other than the site under investigation. A thorough data evaluation should indicate the true nature of the situation.

Air samples should be collected from a minimum of six locations. At least two of these should be background locations. To achieve the required sensitivity for environmental analyses, approximately 300 m^3 will be required. Occasionally, a specific isotope may require special collection efforts. For example, tritium will normally not be collected on filters but on silica gel or other absorbers, and sampling for gases usually requires special equipment and techniques. These special circumstances should be described in the sampling and analysis plan (SAP). The choice of filter material is also important; it is determined by flow rate, the size of the particulate matter being sampled, and the expected loading of the filter during the sampling time. In general, membrane filters are used for low flow rates to detect small amounts of submicron particles, while paper or glass fiber filters are used for larger flow rates and larger particles. Some filter materials contain large amounts of naturally occurring radioactivity (i.e., K-40 in glass fiber filters) and will not be applicable in certain situations.

A maximum of 10 to 12 samples per site can be expected from other sources as indicators of an ingestion pathway.

These may be surface water, sediment, benthic organisms, fish or other indicators. A minimum of two background samples per media should also be collected.

4.2 STRATEGY FOR SELECTING ANALYTICAL METHODS

Currently, there is no single, universally accepted compilation of radiochemical procedures. However, there is a preferred priority of procedures (although developed or approved for other applications) that can be applied to risk assessments.

In general, where the Agency has mandated or recommended radiochemical analytical procedures for compliance with other programs, those procedures should be considered for the same or analogous media when analyzing samples for risk assessments. A key factor in method selection is the constraints that were established during the data quality objective (DQO) process. Exhibit 7 summarizes a preferred order of method selection.

Media-specific procedures are as follows:

Water. Procedures mandated for compliance with the Safe Drinking Water Act (SDWA) should be used for analysis of both surface and groundwater samples for analytes specified in the SDWA. Procedures for analytes not specifically mentioned in the SDWA may be selected from the other compendia listed in Exhibit 8.

Air samples. The National Emission Standards for Hazardous Air Pollutants (NESHAPs): Radionuclides (40 CFR 61 Appendix B) includes methods for the analysis of radioactivity in air samples. This appendix presents both citations of procedures for specific isotopes and general "principles of measurement." The general principles are similar to the counting methods discussed previously. Where the analyte/media combinations match those pathways under investigation at a site, the applicable individual method should be used. When a specific isotope is not mentioned, methods utilizing the appropriate principles of measurement in concert with appropriate QA/QC procedures will be acceptable.

Soil, sediment, vegetation, and benthos. A number of procedures exist that contain methods for the analysis of soil, sediment, and biological media for a variety of radionuclides. Compendia for these procedures are listed in Exhibit 8 and provide ample resources for the selection of analytical methods.

In general, whether the procedures are selected from the SDWA, NESHAPs, or one of the other suggested compilations, the procedures are subject to many limitations. Some procedures assume the presence of only the isotope of interest; some assume the absence of a specific interfering isotope. Procedures involving dissolution or leaching may assume that the element of interest is in a specific chemical form. Careful attention to the conditions and limitations is essential both in the selection of radiochemical procedures and in the interpretation of data obtained from those procedures. If the user is unsure of the applicability of a method to a candidate site or specific situation, assistance can be obtained from the Regional Radiation Representative, Office of Radiation Programs, or radiochemistry staff at the National Air and Radiation Environmental Laboratory in Montgomery, Alabama (NAREL), the Office of Radiation Programs/Las Vegas Facility (ORP/LVF), or the Office of Research and Development-Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL/LV).

EXHIBIT 7. ORDER OF PRIORITY FOR SELECTION OF ANALYTICAL METHODS

- Methods Required by EPA Regulations (e.g., NESHAPs or NPDWR)
- Methods Published by EPA Laboratories (e.g., NAREL, Montgomery, AL or EMSL, Las Vegas, NV)
- National Consensus Standards (e.g., ASTM, APHA, IEEE)
- Methods Published by Other Federal Agencies (e.g., DOE, USGS)
- Methods Published in Refereed Technical Literature
- Methods Published by Other Countries or International Organizations (e.g., IAEA, NRPB)

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EXHIBIT 8. REFERENCES FOR RADIOCHEMICAL PROCEDURES

- American Public Health Association, "Methods of Air Sampling", 2nd Edition, APHA, New York, NY (1977).
- American Society for Testing Materials, "1987 Annual Book of ASTM Standards", ASTM, Philadelphia, PA.
- APHA/AWNA/WPCF, "Standard Methods for the Examination of Water and Wastewater", 17th Ed., APHA, Washington, DC.
- Department of Energy, "RESL Analytical Chemistry Branch Procedures Manual", IDO-12096, VSDOE, Idaho Falls, ID.
- Department of Energy, "EML Procedures Manual", 26th Edition, Report EML-300, USDOE, New York, NY.
- Environmental Protection Agency, "Radiochemical Analytical Procedures for Analysis of Environmental Samples", EMSL-LV-0539-17, USEPA Environmental Monitoring and Support Laboratory, Las Vegas, NV.
- Environmental Protection Agency, "Radiochemistry Procedures Manual", EPA 52015 84-006, EEERF, Montgomery, AL.
- Environmental Protection Agency, "Indoor Radon and Radon Decay Product Measurement Protocols", EPA 520/1-89-009, USEPA, Washington, DC.

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4.2.1 Selecting Analytical Laboratories

☛ *The shipper of radioactive material is responsible for ensuring that the recipient is authorized to receive the shipped material and for compliance with all applicable shipping and labelling regulations.*

The risk assessor needs to be aware of limitations placed on the samples by regulatory or licensing considerations due to the sample's radioactivity content. Adherence to existing regulations is an obvious requirement. Radioactively contaminated sites are likely to generate samples that may be receivable only by laboratories having an appropriate license to handle radioactive materials. Such licenses may be issued by state agencies or the U.S. Nuclear Regulatory Commission (USNRC). In either case, the shipper is responsible for ensuring that the recipient is authorized to receive the shipped material and is responsible for complying with all applicable shipping and labeling regulations (DOT, etc.). Two prerequisites must be filled to permit the shipper to fulfill this obligation:

- A copy of the recipient laboratory's current valid radioactive materials license must be obtained prior to shipment of any samples and be available to the shipper at the location of sample packaging and shipment.
- The shipper must have adequate field measurement equipment available at the site to ensure that samples are within license limits.

Laboratories may have license limits which are specified either on a per sample basis or for the facility as a whole. When facility limits are imposed, the laboratory should be requested to provide its administrative limits on individual samples or sample batch lots. While these requirements do not directly affect the data, compliance with these requirements can be complicated and time-consuming and may interfere with holding times or other analytical requirements. The risk assessor should review the procedures used to comply with these requirements to ensure that such compliance will not affect data integrity.

Many radiochemistry laboratories may not be prepared to associate individual sample data with specific analytical batches. Efficiency calibrations, backgrounds, analytical blanks, instrument performance checks, and other QC parameters all can have varying frequencies and therefore apply to different time periods and different analytical batches. The traditionally applied data qualifiers may not have direct analogues in

radiochemistry or may require alternate interpretation. When receiving data from a mixed waste laboratory which has historically developed from a radiochemistry laboratory, the risk assessor will be required to evaluate different relationships between QC and samples that are typical for non-radiochemical data.

The conventions for the use of data qualifiers are closely tied to data reporting requirements. QA/QC programs for radiochemical laboratories have developed separately with a different emphasis. The emphasis for chemical analysis has been to coordinate the QC data with batches of analyses within fairly narrow time periods. Radiochemical measurement methods emphasize QC data collection based on measurement systems, due to the stability of properly maintained systems and the count-time intensive nature of the analyses. It is not unusual for single measurements to monopolize a given instrument for several hours. It is, therefore, impractical to rerun standard curves at frequent intervals, since other methods of establishing instrument and method performance have been devised.

The probability that non-Contract Laboratory Program (CLP) data or potentially responsible party (PRP) data may have to be used for evaluation will be greater for sites that have more serious mixed waste considerations. Consideration of non-CLP data useage is discussed in Chapter 5. In addition, not all methods may be available for every sample. Availability of a specific method depends on contamination levels and types and levels of containment available at the laboratory. Not all equipment may be available for every level of containment and shielding. It is possible that different equipment or methods may be used for the same parameter in samples with different levels of radioactive contamination. Personnel protection restrictions may limit exposure rates from individual or batch analytical aliquots. Resulting limitations on sample size may be reflected in limitations on the achievable detection limits.

Laboratories performing radiochemical analyses should have an active and fully documented Quality Assurance Program (QAP) in place. There are several documents that provide guidance for the preparation of a QAP. Some of these documents include Test Methods for Evaluating Solid Wastes (SW846) (EPA 1986), United States Nuclear Regulatory Commission Regulatory Guide 4.15 (NRC 1977), United States Department of Energy Environmental Survey Manual (DOE 1988), and ANSI/ASME NQA-1 (ASME 1989). The procurer of radioanalytical services should specify the type of QAP that is required and should be prepared to evaluate programs in such formats. The following are the criteria that are common to these documents and should be considered as the minimum requirements of an adequate QAP:

Quality Assurance Program. The QAP must be written and must state the QA policy and objectives for the laboratory. The primary function of QA/QC is the definition of procedures for the evaluation and documentation of the sampling and analytical methodologies and the reduction and reporting of data. The objective of QA/QC is to provide a uniform basis for sample handling, sample analysis, instrument and methods maintenance, performance evaluation, and analytical data gathering.

Organizational structure. The laboratory should maintain an organizational document defining the lines of authority and communication for reporting relationships. This document should include job descriptions of management and staff, including a QA officer.

Qualifications of personnel. Qualifications of personnel performing quality related tasks should be specified and documented, including resumes, education level, previous training, and satisfactory completion of proficiency testing.

Operating procedures and instructions. Written instructions and/or procedures covering the administrative, operations, and quality levels of the laboratory should be established and include, but are not limited to:

- Sample collection.
- Sample receipt and shipping.
- Analytical methods.
- Radioactive material handling.
- Radioactive waste disposal.
- Data verification.
- Software quality assurance.
- Sample preparation and storage.
- Procurement.
- Quality assessment.
- Chain-of-custody.
- Review of procedures.
- Data evaluation.
- Reporting of data.
- Records.

- Audits.
- Implementation of inter- and intralaboratory QC program.
- Calibration and operation of laboratory instruments.
- Performance checks and maintenance of laboratory instruments.
- Preparation and standardization of carrier and tracer solutions.

The following are criteria that should be considered as additional requirements for an environmental sampling program:

Design control. The laboratory should maintain a document defining the flow path of samples through the laboratory, including sample receipt, sample log-in, sample analysis and measurement, data validation and processing, reporting, and records management.

Inter- and intralaboratory analyses. Reagent blanks, matrix blanks, field (equipment) blanks, field duplicates (splits), laboratory duplicates, blind and double blind matrix spikes, and verification (reference) standards should constitute at least 10% of the samples analyzed. The actual numbers of each type of analysis should be specified in the SAP.

Appropriate QC testing should be included in the work plan for projects other than the established, routine services supplied by the analytical laboratory.

The laboratory should assure that measuring and testing devices used in activities affecting quality are of the proper range, type, and accuracy to verify conformance to established requirements. To assure accuracy, measuring and test equipment should be controlled, calibrated, adjusted, and maintained at prescribed intervals as specified by procedures. Calibrations should be performed using standards or systems that are traceable to the National Institute of Standards and Technology (NIST). If no national standards exist, the basis for calibration should be documented. The method and interval of calibration for each item should be defined. The specifications should be based on the type of equipment, stability characteristics, required accuracy, and other conditions affecting measurement control. Additional routine checks of baseline or background characteristics and performance checks should be made on frequencies appropriate for each instrument with such frequencies established in approved procedures.

Each of the above situations places a greater burden on the risk assessor to perform a careful review. Professional judgment is required to assess the final effect of varying methods, equipment, aliquot sizes, and QA/QC activities on the analytical results.