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Hanford Internal Dosimetry Project Manual PNL-MA-552

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Hanford Internal Dosimetry Project Manual

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Approved for Use and Application by:

10 October 2003

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Preface

This manual is a guide to the services provided by the Hanford Internal Dosimetry Program (IDP), which is operated by the Pacific Northwest National Laboratory.[a] for the U.S. Department of Energy Richland Operations Office, Office of River Protection and their Hanford Site contractors. The manual describes the roles of and relationships between the IDP and the radiation protection programs of the Hanford Site contractors. Recommendations and guidance are also provided for consideration in implementing bioassay monitoring and internal dosimetry elements of radiation protection programs.

A systematic review of the entire manual with appropriate updates to chapters and appendices occurs at three-years intervals, most recently completed in September 2003 and issued in October 2003. Sections not revised with the 10/03 issue date remained current at that time with the issue date shown on the respective pages and in the Table of Contents.

Minor revisions to individual subsections of this manual are made as the need arises.

The recommendations in this manual are provided as guidance, not requirements, to contractor organizations and personnel responsible for designing and operating bioassay monitoring programs. Each contractor determines the extent to which these recommendations apply to the Radiation Protection Program and assigns individual workers to bioassay programs.

The contact person for questions or comments regarding the content of this manual is Eugene H. Carbaugh at 376-6632.

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HANFORD INTERNAL DOSIMETRY PROGRAM MANUAL
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SECTION 1.0, INTRODUCTION

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1.0 Introduction

1.1 The Hanford Internal Dosimetry Program

The Hanford Internal Dosimetry Program (IDP) was initiated in late 1944. By 1946, a routine program had been established at Hanford to assess and document occupational doses to employees from intakes of radionuclides.

The IDP is a sitewide service program operated by the Pacific Northwest National Laboratory (PNNL) for all Hanford U.S. Department of Energy (DOE) and DOE-contractor personnel. The program is funded by Hanford Site contractors and is subject to oversight by the DOE through the Richland Operations Office (RL), the DOE Office of River Protection (ORP), and the Pacific Northwest Site Office (PNSO). It is administered and staffed by Radiation & Health Technology.

Historically, the Hanford Site Services Handbook (DOE 1993) assigned, by charter, the following responsibilities to PNNL:

- assessing and documenting occupational doses from intakes of radionuclides
- determining compliance with applicable internal dose standards
- administering the routine bioassay monitoring program required by site contractors
- providing technical guidance to contractors on internal dosimetry matters
- establishing models for evaluating internal radionuclide deposition
- performing or initiating actions for prompt evaluation of the internal exposure of personnel involved in accidents or emergencies.

The Site Services Handbook was rescinded in 1995, and the IDP now provides the above functions, as specified by the Hanford contractors through contractual statements of work and the Hanford Radiological Health and Safety Document (DOE 2001).

1.2 Program Services

The IDP provides the following services for the benefit of all site employees:

- administering the routine bioassay monitoring program for internally deposited radionuclides
- investigating and documenting evaluations of potential intakes for exposure record files and contractor staff
- arranging for excreta analysis services and ensuring that the Analytical Services Laboratory conforms to the technical requirements of the analytical services contract
- maintaining accreditation for indirect radiobioassay services under the Department of Energy Laboratory Accreditation Program (DOELAP). DOELAP accreditation

- selecting and applying appropriate models, procedures, and practices for evaluating internal radionuclide deposition and the resulting dose

- guiding and supporting Hanford contractors in technical matters regarding internal dosimetry.

Additional specialized services are provided as negotiated with individual contractors.

The IDP is committed to providing cost-effective, quality service that meets or exceeds DOE regulations, uses methods and practices recommended by appropriate national and international organizations, actively explores needed improvements in technology and techniques, and meets DOE guidance to the extent practicable subject to agreement by Site contractors.

1.3 Limitations of Service

IDP capabilities are limited by the degree to which contractors use the available services. The IDP provides consultation and advisory services to contractors for developing and establishing bioassay programs. However, the contractor bears the direct responsibility for ensuring that workers receive adequate and appropriate bioassay monitoring. This includes identifying needs for bioassay monitoring and determining when potential intakes have occurred. The IDP is not responsible for initially reviewing air sampling data or other workplace monitoring data to identify potential intakes. However, review of such data by the IDP is considered germane to an investigation of a potential intake once a potential intake has been identified.

Air sampling, contamination surveys, and other field monitoring techniques provide the primary means of identifying evidence of potential intakes at Hanford facilities. Bioassay monitoring is considered the primary means for confirming intakes, but a secondary means of initially identifying intakes.

It is assumed that each contractor communicates to the workers the need for bioassay measurements and the need to address questions regarding measurements. The IDP staff discuss measurement results with workers on an individual basis if so requested by the contractor, and also deal with specific questions if contacted directly by workers. It is the intent of the IDP that the contractor dosimetry organization be the focal point for all communication with workers regarding dosimetry needs and concerns.

The IDP provides bioassay services that, if properly used, should be capable of identifying and evaluating an intake resulting in a committed effective dose equivalent (CEDE) of 100 mrem or less. However, the capability for such sensitivity depends, in some cases, on prompt identification of potential intakes by the contractor, using workplace monitoring and personnel survey techniques. Periodic bioassay monitoring does not necessarily provide adequate sensitivity to detect intakes resulting in a 100-mrem CEDE.

1.4 Program Direction

Direction for the IDP comes from 10 CFR 835 and the Hanford Radiological Health and Safety Document (DOE 2001). The DOE Internal Dosimetry Program Guide (DOE 2005) is used as general guidance for meeting the requirements of 10 CFR 835. However, in some

used as general guidance for meeting the requirements of 10 CFR 835. However, in some cases, alternate methods may be used that provide similar protection or more cost-effective compliance with 10 CFR 835.

Additional technical guidance is found primarily in the recommendations and standards of the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), the American National Standards Institute (ANSI), the Health Physics Society (HPS), and the DOE.

Specific requirements for individual contractors or clients are contained in Statements of Work or equivalent requirement documents.

1.5 Program Relationships

The IDP works closely with Hanford contractor dosimetry organizations to provide a comprehensive internal dosimetry service. However, the IDP has no direct responsibility to ensure protection of workers, to monitor or conduct surveillance of work environments, to operate facilities, or to assure worker cooperation with bioassay measurement requests. Such items are considered to be the responsibility of the contractor.

The IDP also interfaces with other sitewide service programs operated by PNNL, including the Hanford Radiation Records Program (HRRP), the In-Vivo Monitoring Program, and the Hanford External Dosimetry Program.

The IDP is a member of the Hanford Personnel Dosimetry Advisory Committee (HPDAC), an advisory body consisting of DOE-RL, contractor, and dosimetry program representatives. The HPDAC has been established to review substantive current issues and proposed changes to Hanford personnel dosimetry programs. Its purpose is to identify technical, political, and/or administrative issues necessary to maintaining long-term continuity of such programs, and to ensure technical quality and consistency of dosimetry practices. Decisions and recommendations made by the HPDAC are not binding on the IDP, but they carry significant weight.

1.6 Contents of This Manual

This document, the Hanford Internal Dosimetry Program Manual, is one of three programmatic documents of the IDP. The other two are the Methods & Models of the Hanford Internal Dosimetry Program (PNL-MA-860) and the Hanford Internal Dosimetry Procedures Manual (PNL-MA-5650. The purposes, scopes, and interrelationships of these three documents are described in Chapter 9.0.

This manual also describes:

- the policies upon which the design and operation of the IDP are based (Chapter 2.0)
- the intake and dose assessment process and methods, and good practice recommendations for Hanford contractors to follow in implementing IDP policies in their radiation protection programs (Chapter 3.0)
- internal dose recording and reporting practices (Chapter 4.0)

- recommendations for participation in a bioassay monitoring program, including measurement types, frequencies, and associated minimum detectable intakes or doses (Chapter 5.0)
- the available bioassay services and instructions for obtaining these services (Chapter 6.0)
- the IDP response to potential intake incidents (Chapter 7.0)
- the quality assurance and quality control features of the IDP (Chapter 8.0)
- the program and technical assessment documents and their management and control practices (Chapter 9.0).

In addition, Appendix A lists screening levels for routine bioassay measurements. Appendix B contains tables of data field codes used in the Radiation Exposure (REX) database. Appendix C describes the methods that the Analytical Services Laboratory uses to analyze samples, and Appendix D contains copies of the instructions for each type of sample bioassay kit.

A list of acronyms and abbreviations used in this manual and a glossary of important technical terms, are provided at the end of this document.

1.7 Document Control

Controlled document versions of this manual are administered by IDP. Uncontrolled copies of this manual may be provided for technical or general information, but are not updated and may not reflect the current manual revisions. This manual is also available in an electronic format online at the following URL. http://www.pnl.gov/eshs/pub/pnl552.html.

1.8 References

10 CFR 835. 1999. Department of Energy, *Occupational Radiation Protection.* U.S. Code of Federal Regulations. Available online at http://www.gpoaccess.gov/cfr/.

Pacific Northwest National Laboratory (PNNL). *Methods and Models of the Hanford Internal Dosimetry Program*, PNNL-MA-860. Richland, Washington. (Internal manual.) Available at URL http://www.pnl.gov/eshs/pub/pnnl860.html.

Pacific Northwest National Laboratory (PNNL). *Hanford Internal Dosimetry Procedures Manual*, PNL-MA-565. Richland, Washington. (Internal manual.)

U.S. Department of Energy (DOE) – Richland Operations Office. 1993. *Hanford Site Services Handbook.* RL 1400.1, Richland, Washington.

U.S. Department of Energy (DOE). 2005. *Internal Dosimetry Program Guide* for use with 10 CFR 835. DOE G441.1-3A, Washington, D.C. Available online at http://www.directives.doe.gov.

U.S. Department of Energy (DOE) – Richland Operations Office. 2001. *Hanford Radiological Health and Safety Document.* DOE/RL-2002-12, Richland, Washington.

HANFORD INTERNAL DOSIMETRY PROGRAM MANUAL
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SECTION 2.0, PRACTICE OF THE HANFORD INTERNAL DOSIMETRY PROGRAM

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2.0 Practice of the Hanford Internal Dosimetry Project

It is IDP policy to comply with 10 CFR 835 and the Hanford Radiological Health and Safety Document (DOE 2001). Similarly, it is IDP practice to follow, to the extent practical, the guidance and good practice recommendations issued through the DOE Internal Dosimetry Program Guide (2005), the International Commission on Radiological Protection (ICRP), National Council on Radiation Protection and Measurements (NCRP), U.S. Environmental Protection Agency (EPA), DOE, Health Physics Society (HPS), and American National Standards Institute (ANSI).

This chapter describes the conduct of the IDP and provides for interpretation of applicable regulations and guidance for use at Hanford. The Hanford Personnel Dosimetry Advisory Committee (HPDAC) has reviewed and concurred with these practices described here. Modifications to these practices require endorsement by the HPDAC.

2.1 Assessment and Documentation of Internal Dose

This section presents criteria used to assess, document, and revise internal doses at Hanford.

2.1.1 Criteria for Assessing Internal Dose

Assessment of potential internal exposure is conducted for

- any potential occupational intake reported to PNNL Internal Dosimetry staff by site radiation protection organizations with a request for dose assessment.
- any bioassay measurement that indicates a potential occupational intake that has not been evaluated previously, resulting in a committed effective dose equivalent greater than 10 mrem. This screening level is suitable for occupational workers, as well as minors and members of the public.
- single or cumulative exposures to airborne radioactivity that result in greater than 10 DAC-hours exposure in a calendar year, after correction for respiratory protection.
- any "baseline" bioassay measurement indicating a detectable intake that has not been evaluated previously and that is not readily associated with a non-occupational source.
- any employee, hired by RL, ORP, PNSO or a DOE contractor, who has incurred an occupational intake or internal dose considered significant by the former employer relative to regulatory guidance in place at the time of intake.

The initial assessment generally should include bioassay measurements to confirm the intake. To the extent practicable, measurements should consist of at least:

- one bioassay measurement following a workplace indication of an intake, or

- two bioassay measurements following a bioassay indication of an intake.

Assessments performed as a result of occupational intakes or assigned doses previous to Hanford employment may not necessarily warrant Hanford measurements.

A potential intake is considered to be confirmed if:

- a bioassay result exceeding the decision level (and the environmental screening level, if applicable) is associated with a known incident, or

- a bioassay result not associated with a known incident, exceeding the decision level and the screening level, is followed by two consecutive bioassay measurements, one of which exceeds the decision level or screening level.

- An occupational internal dose is assigned.

If follow-up measurements are not obtained following a bioassay result that exceeds the decision and screening levels, an intake will be assumed to have occurred unless there is overriding evidence that one did not. In this circumstance the assumption of an intake is taken as "confirmation" and any appropriate internal doses will be calculated, recorded, and reported. The overriding evidence must be discussed in the evaluation.

Hanford visitors whose baseline bioassay measurements detected radioactivity and whose end-of-assignment measurements are consistent with their baseline measurements will not have their prior occupational dose assessed by Internal Dosimetry unless the site contractor requesting the measurements specifically requests Internal Dosimetry to do so. Instead, the requesting site contractor and the Hanford Radiological Records Project (HRRP) staff will be notified by letter of the activity detected.

2.1.2 Dose Assessment Practices

The estimation of internal dose shall be based on bioassay data rather than air concentration values unless bioassay data are unavailable, inadequate, or estimates based on representative air concentration values are demonstrated to be as, or more, accurate. The determination that bioassay data are inadequate, or air concentration values are more accurate will be made on a case-by-case basis by the internal dosimetrist, in consultation with the facility's radiological control organization, and at least one other internal dosimetrist. Generally, air sample data would be used for radionuclides with physical or effective half-lives that are too short to accomplish bioassay measurements, e.g., radon/thoron progeny or when likely low-level intakes are below the bioassay detection capabilities. Prior-to-Hanford exposure

expressed in working level months, MPC-hours, or DAC-hours will be converted to internal dose according to methods established in program documentation without consulting Field Dosimetry.

CEDEs Less Than 500 mrem

If the available evidence suggests that the committed effective dose equivalent (CEDE) from an intake does not exceed 500 mrem and specific information is not readily available, generalized (default) models and assumptions may be used to assess the dose. These general assumptions are as follows:

- The intake occurred by inhalation.
- The intake is acute.
- If the actual intake date is unknown, the intake occurs at the midpoint to the potential exposure period for acute intakes or through the potential exposure period for chronic intakes.
- For monitored workers, the potential exposure period extends back one monitoring period unless known to be otherwise.
- The radionuclides observed in bioassay measurements, or otherwise known to be present, are included in the assessment. All radionuclides potentially involved in the exposure are considered, including those not specifically identified in the initial bioassay measurements but expected to be present.
- The physiological characteristics of the workers are the same as those of the Reference Man or Woman in ICRP 23 (1974).
- The biokinetic models and parameters described in *Methods and Models for Hanford Internal Dosimetry*, PNNL-MA-860 are to be used for radionuclides included in that document; otherwise, models and parameters endorsed or prescribed by the NCRP or ICRP are to be used.
- The dose to the embryo/fetus is calculated separately from the dose to the mother.

CEDEs Above 500 mrem

At projected CEDEs above 500 mrem, actions are taken as follows:

- Bioassay and exposure characterization data are obtained to enable adjustments to be made to the default assumptions and models, as appropriate.
- Consideration may be given to individual-specific physiological characteristics.

Recording Doses

Dose equivalents are recorded as calculated for each assessment, with the following special provisions:

- Quantified doses of less than 10 mrem are rounded to the nearest whole number, and doses of 10 mrem or greater may be rounded to two significant figures.

- Organ dose equivalents are recorded for any organ contributing more than 10% to a CEDE exceeding 100 mrem. This criterion applies to each intake separately, even if a worker has more than one intake a year. (For radionuclides such as tritium and radio-cesium, which provide dose homogeneously to all organs, the dose may be recorded as effective dose; however, it is understood that the same dose applies to all organs.)

- Committed organ and effective dose equivalents will be assigned to the year of intake.

2.1.3 Documentation of Dose Assessments

Assessments of occupational internal doses are documented. The documentation includes or references the methods, assumptions, and data used to make the assessment and lists the assessed dose equivalents. A copy of the documented assessment is provided to HRRP for placement in the worker's radiation exposure file. For each assessment, a letter is sent either to the worker directly or to the worker's radiation dosimetry organization. The letter summarizes the conclusion of the assessment and updates the worker's current internal dose status.

Intake assessments are issued within 3 months of obtaining all the necessary data (including bioassay and source-term characterization). Alternative completion times are negotiable with customers considering the priority of specific evaluations and the total evaluation workload. Customers will be notified if lower-priority evaluations are rescheduled beyond the 3-month target because of other expedited evaluations.

Chronic intakes are assessed on a calendar-year basis for continuing exposures.

2.1.4 Dose Assessment Revisions and Updates

The dose assessment for an active worker with a prior intake will be reviewed and updated at the request of the contractor dosimetry organization. In addition, workers maintained on bioassay for radionuclides previously evaluated are reviewed in light of the previous evaluation each time that new measurements are obtained, and a determination is made as to the consistency of the current results with the anticipated results. If results are not consistent, then the reason for the discrepancy is investigated.

Assessments for active workers are revised when information demonstrates a change in the currently assessed committed effective dose equivalent of 0.5 rem or a factor of 1.5 of the previously assigned dose for that intake, whichever is higher.

When the revision involves a specific worker's intake, the contractor dosimetry representative is notified, in advance, of the need to issue a revised assessment.

When the revision results from general changes in dosimetry techniques, assumptions, or regulations, and multiple workers are affected, then Internal Dosimetry presents a discussion of the impacts of the change to the Hanford Personnel Dosimetry Advisory Committee.

2.2 Internal Dose Reports

Internal Dosimetry provides reports of internal dose to contractor dosimetry organizations and to HRRP as described in the following subsections.

2.2.1 Reports Provided to Contractor Dosimetry Organizations

A final assessment summary letter is provided to the worker and/or contractor dosimetry organization upon completion of the intake evaluation report. Preliminary assessments (verbal or written) are provided upon request. The summary letter contains the following information:

- the identity and magnitude of any confirmed occupational intake
- committed effective dose equivalent for a confirmed occupational intake
- committed organ dose equivalents to significant organs when the CEDE exceeds 100 mrem
- date of intake
- facility at which intake occurred
- any long-term follow-up bioassay recommendations.

It is the contractor's responsibility to report the worker's annual TEDE and dose status relative to any control levels.

2.2.2 Reports Provided to the Hanford Radiation Records Program

The IDP provides internal dose information to the Hanford Radiation Records Program for inclusion in the Radiation Exposure (REX) System.

2.3 Bioassay Monitoring Program

The HIDP maintains accreditation for indirect radiobioassay under the Department of Energy Laboratory Accreditation Program (DOELAP), as required by 10-CFR 835.402(d)(1). Accreditation is maintained for DOELAP-proffered radionuclides or categories of radionuclides which are of concern at Hanford. Criteria for accreditation are described in DOE-STD-1112-98 (DOE 1998). The letter and certificate granting accreditation are maintained in the program Records Inventory and Disposition (RIDS) Schedule, with copies provided to the Historical Files and the HPDAC. The DOELAP accreditation for direct radiobioassay measurements at Hanford is maintained by the In Vivo Monitoring Program.

Internal Dosimetry provides, to the extent that Hanford Site contractors and RL/ORP/PNSO will support and that technical capabilities will allow, a bioassay monitoring program capable of detecting an intake potentially resulting in a CEDE of 100 mrem.

Facility-specific radionuclide mixtures and characteristics are considered in the development of the bioassay-monitoring program. Bioassay capabilities are optimized, considering sensitivity requirements and costs.

2.3.1 Objectives for Periodic Bioassay Monitoring

The following objectives are established as guidance for cost-effective bioassay monitoring programs which comply with 10 CFR 835.

- The 100-mrem sensitivity does not have to be achieved for all radionuclides measured if workers are not potentially exposed to those radionuclides.

- The 100-mrem sensitivity does not have to be achieved for confirmatory monitoring (i.e., limited surveillance to verify periodic monitoring is not required). Minimum detectable dose (MDD) calculations are not appropriate for confirmatory monitoring.

- For radionuclides or mixtures of radionuclides for which existing bioassay methods and frequencies achieve the 100-mrem sensitivity recommendation, changes should not be allowed that degrade the sensitivity to where the MDD exceeds nominally 100-mrem. This does not preclude the switching of one bioassay method for another to best accomplish Site needs so long as the resulting MDD stays less than 100 mrem.

- For radionuclides or mixtures of radionuclides for which existing bioassay methods and frequencies do not achieve the 100-mrem sensitivity recommendations, changes should be discouraged that significantly degrade the sensitivity.

For radionuclides or mixtures of radionuclides for which existing bioassay methods and frequencies do not achieve the 100-mrem sensitivity

recommendation, the weighting given for cost and inconvenience of the bioassay method decreases as the MDD increases. However, it is recognized that for mixtures composed principally of actinides, the best intake-monitoring program is provided by aggressive workplace monitoring and prompt initiation of special bioassay.

A grace period for all bioassay samples, during which no work restriction is imposed, consists of the calendar month in which the sample is scheduled (the due period) and the immediately following calendar month (the probation period) An excreta sample or in vivo measurement not obtained during the due period is considered late on the first day of the probation period, and delinquent following the end of the grace period. Late bioassays warrant attention to make sure they are obtained during the probation period. Failure to comply with a bioassay request by the end of the grace period should result in a work restriction for the worker until the in vivo measurement is obtained or the excreta sample is provided to the laboratory. The work restriction may be lifted following a receipt of a valid sample. No work restriction should be imposed for a failed analysis, however the grace period will immediately resume with the reporting of the failed analysis.

2.4 Program Documentation

The practices and general recommendations of the IDP are documented in this controlled distribution manual. Copies of the manual and updates to the manual are maintained in the Hanford Radiation Protection Historical Files.

Suggestions and recommendations for specific work situations, radiation work permits, or facilities may alternatively be documented in letters, memorandum, or special reports. Such guidance supersedes that contained in this manual. A copy of such guidance will be included in the Historical Files.

Changes in general practices and recommendations presented in this manual are made by Interim Change Notices or manual revisions. Changes are distributed to the controlled distribution for the appropriate document. A copy of the change is maintained in the Historical Files.

The following items are also documented or referenced in the Historical Files and program RIDS (discussed in Section 9):

- operating procedures
- technical bases
- biokinetic models
- computer codes
- Excreta Laboratory Statement of Work
- QA Plan

- DOELAP Accreditations

- Facility – specific internal dosimetry or bioassay design and characterization documents

2.5 References

10 CFR 835. 1999. Department of Energy, *Occupational Radiation Protection.* U.S. Code of Federal Regulations.

International Commission on Radiological Protection (ICRP). 1974. *Report of Task Group on Reference Man.* ICRP Publication 23, Pergamon Press, New York, New York.

Pacific Northwest National Laboratory (PNNL). *Methods and Models of the Hanford Internal Dosimetry Program*, PNNL-MA-860. Richland, Washington. (Internal manual.) Available at URL http://www.pnl.gov/eshs/pub/pnnl860.html.

U.S. Department of Energy (DOE). 1998. *DOE Standard The Department of Energy Laboratory Accreditation Program for Radiobioassay.* DOE-STD-1112-98, Washington, D.C. Available online at http://www.directives.doe.gov.

U.S. Department of Energy (DOE). 2005. *Implementation Guide for Internal Dosimetry Program Guide* for use with 10 CFR 835. DOE G441.1-3, Washington, D.C. Available online at http://directives.doc.gov.

U.S. Department of Energy (DOE) – Richland Operations Office. 2001. *Hanford Radiological Health and Safety Document.* DOE/RL-2002-12, Richland, Washington.

3.0 Internal Dose Assessment

The process of assessing internal dose involves collecting and analyzing information concerning a potential intake, and then developing a conclusion regarding the magnitude of the intake in terms that can be related to radiation protection standards. In a broad sense, the dose assessment process consists of three parts:

- identifying a potential intake
- collecting pertinent data
- evaluating and documenting intake magnitude and dose equivalent.

A successful intake assessment effort at Hanford depends on the support of both the contractor dosimetry organization (i.e., Field Dosimetry) and the IDP. Field Dosimetry has the primary responsibility for identifying potential intakes for assessment. Internal Dosimetry supports this effort by providing guidelines and recommendations for establishing routine bioassay monitoring programs and for identifying situations that warrant intake assessment (see Chapters 5.0, 6.0, and 7.0). The performance of bioassay measurements and the collection of other data and information used in the assessment require the combined efforts and cooperation of Field Dosimetry and Internal Dosimetry.

Evaluating the data, assessing internal dose, and documenting the assessment are primarily the responsibility of Internal Dosimetry, as discussed in this chapter.

3.1 General Description of an Intake Assessment

Determining when and what kind of an assessment of potential intake is necessary, and how the assessment is conducted for various intake scenarios, is key to the assessment process.

3.1.1 Criteria for Performing an Assessment

Program practice statements in Chapter 2.0 establish the criteria for determining when an intake assessment is needed and provide the general guidance used in performing the assessment.

3.1.2 Types of Assessments

Assessments of potential intakes generally fall into one of three categories:

- preliminary evaluation
- final evaluation
- reevaluation.

Preliminary Evaluation

The purpose of the preliminary evaluation is to provide a prompt or interim assessment of the potential seriousness of an intake prior to obtaining the data required for a final evaluation. Because the preliminary evaluation is performed before completing the investigation, the estimates of intake and dose are based on relatively conservative assumptions. Thus, preliminary evaluations tend to result in a higher assessed dose than do final evaluations.

In cases where the significance of the potential intake is obviously small, the conclusions of the preliminary evaluation are reported verbally. For cases with greater significance, Field Dosimetry may request a written preliminary evaluation.

Final Evaluation

A final evaluation represents the conclusion of the intake assessment process based on the follow-up investigation. (See Exhibit 3.1, Internal Dose Evaluation Report Form, at the end of this chapter.) A report on the final evaluation is generally issued within 3 months of the receipt of the necessary data, with some exceptions as mentioned in Section 2.1.3. Generally, the time period between identifying an intake and issuing a final report ranges from 1 month, for simple cases, to 1 year, for complex cases requiring long-term bioassay data. Final evaluations may be revised by issuing a reevaluation report if additional evidence that affects the conclusion of the previous final evaluation is obtained.

Reevaluation

A reevaluation is an updated final evaluation report. The criteria for determining when a reevaluation should be performed are provided in Section 2.1.4.

3.1.3 General Approach

Intake assessments are conducted by investigating the nature of the exposure and by analyzing bioassay measurement results and other pertinent data. Bioassay measurement data, which provide information on the deposition and retention of radionuclides in the involved individual(s), are the preferred basis for assessing internal dose. In cases where bioassay data are not available, an internal dose assessment can be made using other relevant information that is available, such as air sample data, source terms, and contamination surveys.

3.1.4 Intake Assessment Situations

Various situations necessitate an assessment of potential intake. Table 3.1 lists possible situations for which an assessment may be needed and the criteria used to determine whether an assessment should be initiated.

3.2 Performing the Assessment

When one of the situations in Table 3.1 occurs and the dose assessment criteria are met, an evaluation of potential intake is performed. The assessment process includes investigating the potential intake, documenting the results, and reporting the conclusions. Figure 3.1 depicts the steps that make up the complete assessment process. (The Internal Dose Evaluation Report is described in Section 3.2.2. See Chapter 4.0 for information on the INTERTRAC and REX databases.)

3.2.1 Investigation of a Potential Intake

The investigation phase of the assessment process involves the performance of special bioassay measurements and the collection of other pertinent data. Special bioassay measurements have three purposes:

1. identifying (confirming) that an intake occurred

2. establishing the material's distribution in and clearance from organs in the body.

3. assessing dose equivalent

Recommendations for special bioassay measurements are made by Internal Dosimetry on a case-by-case basis, according to stated practices in Chapter 2.0 and other guidance provided in Chapters 6.0 and 7.0, Appendix E, and with the concurrence of Field Dosimetry. The type and extent of the measurements depend on the significance and complexity of the case.

Special measurements for assessing dose are based on the need to establish the magnitude of the internal deposition and its clearance rate from the body. Generally, the frequency for performing special bioassay measurements can be decreased with time post-intake, until, for long retained nuclides, the measurements can be continued on an annual monitoring frequency. It is recommended that special bioassay measurements continue until the measurement results are consistently less than detectable or below the screening level established for routine bioassay monitoring. Other information that may be important to the assessment is listed in Table 3.2.

The investigation determines whether an intake occurred. If the conclusion is that an occupational intake did occur, the magnitude of the intake or deposition and the CEDE are determined and assigned. If an occupational intake is not confirmed, no dose is assigned.

TABLE 3.1. Potential Intake Assessment Situations

Situation	Criteria for Initiating a Potential Intake Assessment
Field Dosimetry identifies a potential intake incident.	Field measurement data meet contractor criteria for potential intake. (Recommendations for these criteria are provided in Chapter 7.0.)
Special (nonroutine) bioassay measurement shows detectable activity above natural background.	Measurement results indicate internally deposited radionuclides.
Routine bioassay measurement shows activity.	Measurement results exceed the screening level of the routine bioassay monitoring program. (See Appendix A.)
Bioassay result for a worker with a known internal deposition shows an unanticipated increase.	When recent and previous bioassay measurements are compared, it is determined that the recent result exceeds normally expected fluctuations.
Bioassay data collected subsequent to an evaluated intake suggest that the assigned dose may be incorrect.	Evidence suggests that the assigned CEDE may be in error by 0.5 rem or a factor of 1.5 of the previously assigned dose, whichever is higher.
Field Dosimetry requests a special internal dose assessment.	Request by Field Dosimetry.
Prior work history or baseline bioassay measurement for a newly hired employee indicates a previously incurred occupational intake.	Bioassay or other information indicates internally deposited radioactivity at the time of employment.

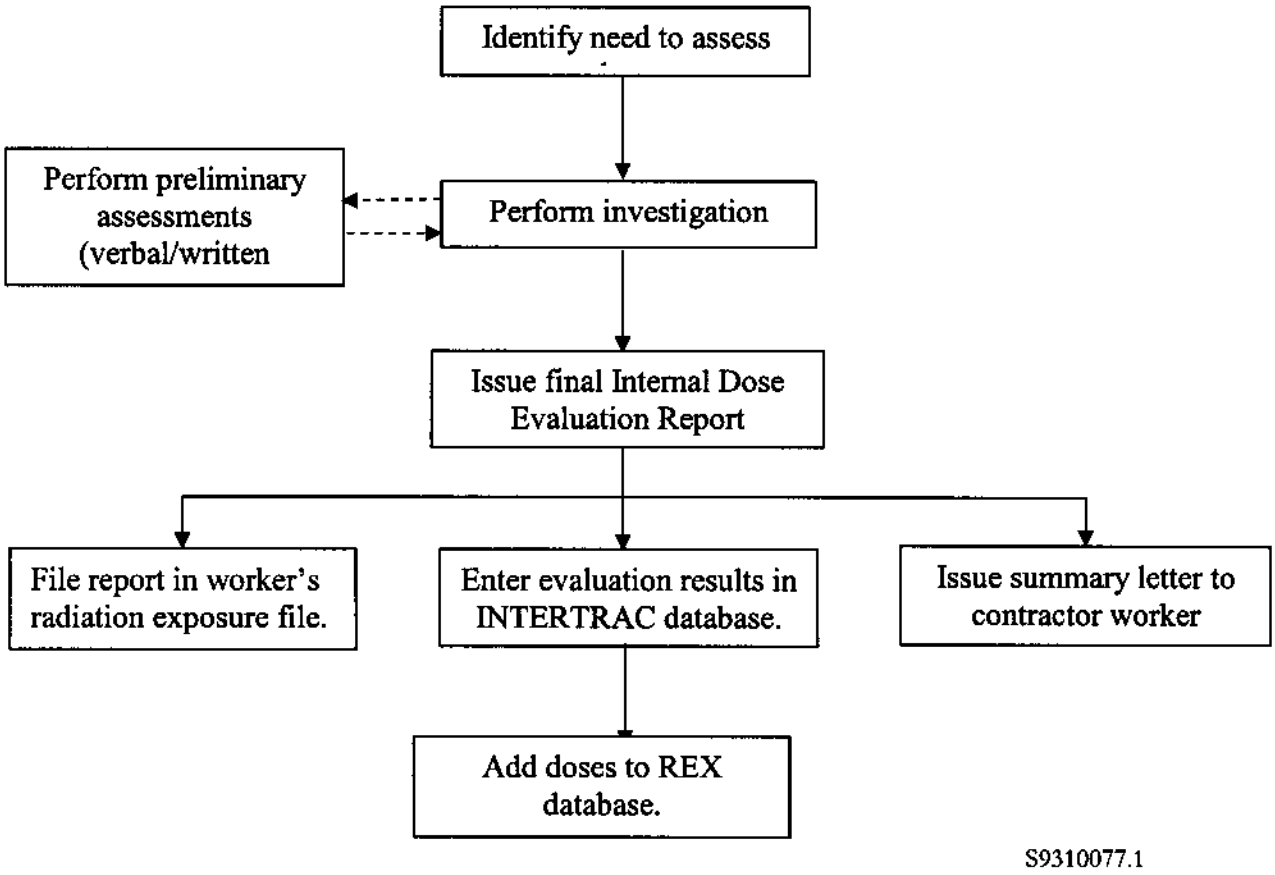


FIGURE 3.1. Internal Dose Assessment Process

3.2.2 Documentation

Internal Dose Evaluation Report

Occupational intakes of radionuclides are assessed and formally documented through the Internal Dose Evaluation Report. This report describes the methods, assumptions, data, and conclusions of the assessment. All subsequent detailed or summary accounts of internal dose from a particular intake are derived from the report.

Internal Dose Evaluation Reports are prepared by Internal Dosimetry, using methods and assumptions described in this manual, in the internal manual *Methods and Models of the Hanford Internal Dosimetry Program (PNNL-MA-860)*, and in other resources, as appropriate. Before any report is issued, it is reviewed internally by a peer internal dosimetrist.

Exhibit 3.1 (at the end of this chapter) shows the form used to document Internal Dose Evaluation Reports. This form is used to identify the assessment, organize the content of the report, summarize the conclusions, and identify the staff that prepared and reviewed the report. When an assessment is complex, special attachments containing the details of the assessment are included with the form.

Each internal dose evaluation is identified by a unique identification number. Prior to 1987, numbers were assigned sequentially. Beginning on January 1, 1987, the numbering system was revised to include a five-digit event number, followed by a two-digit person designator and a one-digit evaluation revision designator. The first two digits of the event number represent the calendar year during which the evaluation was originally initiated, and the next three digits are assigned sequentially to each event during that year. The sequence character after the two-digit individual worker number indicates that the evaluation report is either the original (A) or a revision (B,C,D...). For example, the evaluation number "87005-02A" identifies the evaluation as the original version issued for individual number 2, who was involved in the fifth potential internal exposure event of 1987.

Evaluation numbers are assigned by the Internal Dosimetry technician upon notification that an assessment will be performed. The evaluation number may also be referred to as the Dose Evaluation Management System (DEMS) number, which is used to track evaluations.

The following information is provided in the evaluation report:

- the evaluation number
- the worker's name, payroll number, and social security number
- the date or period of exposure (actual or assumed)

- the area and building where the exposure occurred or is assumed to have occurred
- a summary of the exposure scenario, if known
- mode(s) of intake (actual or assumed)
- Contractor statement of appropriate source term radionuclides, or a concurrence with the evaluation assumptions. This item is not required for routine tritium oxide assessments, unconfirmed high routine tritium oxide assessments, unconfirmed high routine measurements or for situations with source terms well established in technical basis documentation.
- radionuclides addressed by the assessment.
- Contractor statement of the measured or calculated determination of air sample representativeness if dose is to be assigned based on air sample results or DAC-hours record. (Not required if assessment is based on records from prior employer.)

The evaluation report also contains:

- a summary of data used in the assessment
- a description of assessment methods and assumptions
- Intake magnitude and identity
- CEDEs
- the committed dose equivalent to organs meeting the criteria in Section 2.1.2
- references, as required
- the author's name and signature
- the peer reviewer's signature.

TABLE 3.2. Information Supporting the Internal Dose Assessment

Information Type	Examples
General Information	Location where exposure occurred Description of the exposure event, including time, suspected mode of intake, duration of intake, and other individuals involved Personnel contamination survey results and decontamination actions Radionuclides involved, including relative abundance in mixtures Physical and chemical characteristics of contamination and host matrix.
Inhalation Intake Information	Airborne radionuclide concentrations Respiratory protection used Observed facial, nasal, and/or other personal contamination Breathing habits (mouth/nose breather).
Absorption/ Wound Information	Location of wound Cause and description of wound Wound contamination survey results Characteristics of contamination in and around the wound site Medical and health physics actions.
Materials for Potential Analysis	Analysis of the following materials can also provide useful information, and it is recommended that, to the extent practical, these materials be identified and retained until the final evaluation report is issued: • air sample media (filters, canisters) • contamination smear survey pads • nasal swab and irrigation fluid • respirator filters • wound debris (blood, tissue, foreign matter).

3.2.3 Assessment Reporting

Summary Letter

A letter summarizing the conclusions of the evaluation is prepared for each evaluation. Summary letters are sent either directly to the worker or to Field Dosimetry, depending on the circumstances of the evaluations and the conclusion.

Sent Directly to Worker

The summary letter is sent by the IDP directly to the worker, with a copy to Field Dosimetry, when it is considered unlikely that the worker will have questions about the evaluation or conclusion. Examples of such conditions include the following:

- No occupational dose was assessed.
- The evaluation was a reassessment and Field Dosimetry concurs with addressing the cover letter to the subject.
- Dose was assigned without obtaining confirming bioassay measurements.
- The intake occurred prior to Hanford employment. Field Dosimetry will be verbally notified if the CEDE exceeds 50 mrem.

The letter should be sent to the worker's Hanford plant address. If there is no plant address or the worker has terminated Hanford employment, the home address will be used. Field Dosimetry will contact the worker's supervisor if that appears to be necessary. Any worker contacting PNNL Internal Dosimetry with questions concerning the evaluation will be referred to Field Dosimetry.

Sent to Field Dosimetry for Communication to Worker

The summary letter is sent to Field Dosimetry, for subsequent communication to the worker by Field Dosimetry, when it is considered likely that discussion about the evaluation may be needed or that the worker may have specific questions. Examples of such conditions include the following:

- The evaluation assigns occupational dose associated with Hanford employment.
- The evaluation is for a Hanford visitor.
- Summary letters will be sent to the event contractor field dosimetry organization if the worker's potential intake occurred in a facility not operated by the worker's employer. A copy of the letter will also be provided to the worker's field dosimetry organization.

Summary Letter Contents

The summary letter contains the following information:

- the worker's name and payroll number

- the date or period of the intake
- the area and building where the intake occurred
- the intake magnitude and identity
- the assigned CEDE and pertinent committed organ doses
- recommendations for further follow-up sampling.

A copy of the evaluation report will be provided to Field Dosimetry upon request. Hanford employees seeking a copy of their evaluation reports should request it through Field Dosimetry. Requests from former Hanford employees are processed by the HRRP staff.

3.3 Dose Assessment Methods

Program practices, discussed in Chapter 2.0, provide general statements regarding the operation of the IDP. Technical considerations for the internal dose assessment process are covered in PNNL-MA-860. The methods and approaches used for investigating, evaluating, and reporting internal dose assessments are summarized in this section. These "default" methods are used unless available information points to a more appropriate method or assumption. If methods and techniques other than those discussed here are used, they are to be documented in the evaluation report.

3.3.1 General Approach

Intakes are preferably assessed based on bioassay measurement results. However, if bioassay data are unobtainable, the assessment is performed using any relevant information that is available.

Direct (in vivo) measurements of internal content and retention patterns are preferred to indirect (excreta) methods that require the use of excretion functions and biokinetic models.

Assumptions used in the dose assessment process should be conservative but realistic. Caution should be exercised when multiple conservative assumptions could compound errors and result in an unrealistic estimate. Assumptions should not be made when actual data or information are available.

The expected baseline from any past intake must be factored into evaluations of any new intake.

When the actual intake time or period is not known, it is necessary to identify the probable intake date(s). This may be done by considering available evidence, such as air monitoring results, contamination surveys, operating

periods, and previous bioassay measurement results. After the intake time is narrowed to a probable time period, it is assumed that an acute intake occurred at the midpoint of that period. If the evidence suggests that a chronic intake is more reasonable, it is assumed that the chronic intake occurred uniformly throughout the probable exposure period.

If the mode of intake is not known, it is assumed that the intake was by inhalation.

Uncertainties in internal dose assessments are presently not quantifiable. Almost any factor in the internal dose process can result in a change of 50% or more. The possible factors are numerous, e.g., the number of bioassay measurements taken, assumed intake date, particle size, solubility in lung fluid, solubility in blood at the wound site, actual versus reference excreta levels, organ sizes, clearance and retention half-times, accuracy of corrections for skeletal, liver, or lymph system contents, differences in metabolic behavior between ionic material and material bound in a parent-material matrix, etc. The evaluation philosophy is to weigh the merits of default assumptions versus obtaining additional data on a case-by-case basis. Default assumptions are used when no other data is available.

3.3.2 Evaluating Lung Dose for Inhalation Exposures

Potential lung doses from inhalation exposures must be considered, even if direct in vivo measurements do not identify the nuclide in the lung. In such cases, assessments of the lung burden and dose should be performed using alternative techniques, such as excreta measurements, air samples, or other available information. However, the assessed activity in the lung should not exceed the reported minimum detectable activity (MDA) level of the chest measurement.

3.3.3 Solubility and Particle Size Assumptions

Input terms for biokinetic models should be based on field data and on bioassay measurements that are specific to the intake being evaluated. If the model requires input values that cannot be reasonably obtained, appropriate conservative assumptions should be used. The default particle size for the biokinetic model of the respiratory tract is 5μm AMAD (activity median aerodynamic diameter for workers). The transportability characteristics should be determined based on the known or probable chemical and physical makeup of the material. The evaluation should include appropriate discussion of the rationale for choosing these parameters.

3.3.4 Radionuclides Included in the Assessment

The internal dose assessment should consider all radionuclides that are identified by in vivo or field measurements, as well as additional radionuclides that are reported by Field Dosimetry as being present or that are known to be present from previous experience. If field measurements indicate gross radioactivity levels only (gross beta, gross alpha), appropriate radionuclide representations of these levels should be used, based on a conservative evaluation of radionuclides potentially present. Reference radionuclide mixtures developed PNNL-MA-860 can be considered applicable in this situation. Field Dosimetry will provide characterization data appropriate for assessing confirmed Hanford intakes, or concur in the characterization used for the assessment. This characterization shall be documented in the evaluation.

3.3.5 Assessment of Exposures of Localized Tissue

For radionuclide depositions in localized tissues, such as in regional lymph nodes or at wound sites, the quantity of the radionuclide deposited in the tissue and its projected clearance half- time are assessed and documented. The assessment becomes part of an individual's radiation exposure file, but it is not used for determining compliance with either stochastic or nonstochastic dose equivalent limits. Additional discussion is provided in Section 2.5 of the *Methods and Models of the Hanford Internal Dosimetry Program (PNNL-MA-860).*

3.3.6 Biokinetic Models

Biokinetic models for specific applications are discussed in the *Methods and Models of the Hanford Internal Dosimetry Program (PNNL-MA-860).* The standardized models summarized below are used for initial evaluation of internal exposure. These models are applied to final evaluations unless a more appropriate model is determined to apply to the specific exposure situation.

Respiratory Tract Model

The general model for the respiratory tract presented in ICRP Publication 30 (1979) or ICRP Publication 66 (1994) is used to evaluate retention and elimination of inhaled particulates by the respiratory system.

Gastrointestinal Tract Model

The model for the gastrointestinal (GI) tract presented in ICRP Publication 30 (1979) is used to evaluate retention and absorption of materials by the stomach and small and large intestines.

Systemic Retention Models

The systemic retention models used are those described in *Methods and Models of the Hanford Internal Dosimetry Program (PNNL-MA-860).* Generally, the models used are based on the concepts and models of the ICRP. Retention models are most useful when organ uptake and retention cannot be determined using in vivo measurements.

Systemic Excretion Models

The systemic excretion functions listed in Table 3.3 are applied to excreta data unless a more appropriate model applies to a specific situation. The

models are discussed further in the *Methods and Models of the Hanford Internal Dosimetry Program (PNNL-MA-860)*..

3.3.7 Computer Programs Used for Dose Calculations

The computer program codes listed in Table 3.4 are consistent with the retention and/or excretion models discussed previously. The codes are used in the assessment process unless another approach is determined to be more appropriate for the specific situation. Each of the computer programs is documented in the Hanford Radiation Protection Historical Files.

TABLE 3.3. Excretion Functions

Element	Systemic Excretion Model
Plutonium	Jones function (Jones 1985)
Strontium	Alkaline earth model, as implemented by CINDY computer code
Uranium	ICRP Publication 30 (1979) retention model
Tritium	ICRP Publication 30 (1979) retention model

TABLE 3.4. Computer Programs Used for Dose Calculations

Computer Program Code Name	Purpose
CINDY	A dosimetry code specifically developed by DOE for implementing the ICRP-30 techniques and models.
PUCALC	A set of programs for estimating systemic uptake of plutonium from urine data.
AMERIN	A code for calculating biological half-life and ingrowth for mixtures of ^{241}Am and ^{241}Pu.
Pu.EXE	Utility for determining isotopic composition of aged plutonium mixtures
IMBA	IMBA Expert ™ USDOE Edition. A comprehensive internal dosimetry code implementing the ICRP 66 respiratory tract model and advanced recycling biokinetic models of ICRP.

3.3.8 Simplified Dose Assessments

The simplified dose assessment procedure is a standardized approach for assessing internal doses. The procedure is generally employed for

- calculations used in bioassay program design
- initial dose assessments when available bioassay and other data regarding the exposure are minimal
- final assessments for which the dose equivalent is relatively low.

Generally, the simplified dose assessment procedure is used for the final assessment of intakes resulting in CEDEs of less than 100 mrem.

The simplified dose assessment procedure employs the standardized excretion and retention functions and assumptions discussed previously in this section, as well as specific assumptions and methods described in the *Methods and Models of the Hanford Internal Dosimetry Program (PNNL-MA-860)*..

If the assessed dose calculated using the simplified dose assessment procedure exceeds 500 mrem CEDE, then models, methods, and assumptions are reviewed to determine their applicability.

3.3.9 Dose Assessment Flowcharts

Flowcharts have been developed to guide the assessment process for several situations where doses are usually small and may be complicated by environmental rather than occupational sources. These flowcharts were developed to allow practical decisions to be made without severely impacting the worker or the work when the consequences of a wrong decision are small. The following flowcharts and supporting items are provided at the end of this chapter:

Exhibit	Title
3.2	Determining Occupational and Nonoccupational Intakes
3.3	Baseline Samples - Tritium
3.4	Baseline Samples - Elemental or Isotopic Uranium
3.5	Chronic Exposure Assessment – for soluble Uranium (class D) or similar with quarterly or more frequent monitoring.
3.6	Detection of Cesium-137 in the Whole Body Exam
3.7	In Vivo Exam Questionnaire
3.8	Review of Elemental Uranium Urinalysis Results

3.3.10 Internal Dose Assessment to the Embryo/Fetus

The internal dose to the embryo/fetus considers contributions from radionuclides deposited in the embryo/ fetus and dose equivalent arising from radionuclides deposited in the declared pregnant woman. Unless better information is available, the dose calculation methods described in the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 8.36, "Radiation Dose to the Embryo/Fetus" (NRC 1992), or ICRP Publication 88 (ICRP 2002) shall be used.

3.4 Good Practice Recommendations for Field Dosimetry

Monitoring and assessing intakes at Hanford are accomplished through the mutual effort and cooperation of the IDP and Field Dosimetry. These activities are complementary; that is, the responsibilities of both the contractor and Internal Dosimetry must be fulfilled. The following recommendations are suggested by Internal Dosimetry as general guidance for Field Dosimetry administration of monitoring programs. In addition to this general guidance, Internal Dosimetry provides specific guidance and technical support as needed.

3.4.1 Identifying Routine Bioassay Monitoring Needs

The following good practice recommendations cover activities that are required for a complete internal dosimetry program:

- Identify the routine bioassay monitoring needs of individuals and arrange for a routine bioassay monitoring program that is responsive to

these needs. The bioassay monitoring program should be radionuclide-specific; that is, the program should be established by radionuclide and exposure scenario, rather than by measurement type. General guidance on the needs of the bioassay monitoring program is provided in Chapter 5.0 of this manual. Internal Dosimetry can recommend measurement types to ensure the inclusion of radionuclides of concern.

- Apprise Internal Dosimetry of the radiological conditions in facilities. Include identification and physical and chemical characteristics of the radionuclides, as well as the potential internal exposure situations that exist.

- Contact Internal Dosimetry as needed for specific guidance and support in the setup and operation of the routine bioassay monitoring program.

- In cooperation with Internal Dosimetry, identify the radionuclides for which bioassay monitoring is not performed or is not adequate, and ensure that appropriate monitoring of these radionuclides (using other techniques) is provided. This could apply, for example, to short-lived radionuclides that cannot be reliably detected through routine bioassay monitoring.

- Maintain procedures for collecting workplace and personnel monitoring data, evaluating the data, documenting the results, and maintaining records.

3.4.2 Identifying Potential Intakes

Identify potential intake events and report these promptly to Internal Dosimetry. Assessments of internal dose are more accurate and can be performed with less expense if the intake time is known, if follow-up samples are collected shortly after intake, and if field data are available regarding the nature and characteristics of the exposure. Special bioassay measurements should be obtained if a worker incurs a potential intake of 0.02 ALI in an incident or over a short period of time.

3.4.3 Managing Internal Dose

Good practice in managing internal dose includes adhering to the following recommendations:

- Avoid potential intakes to workers until baseline bioassay measurements have been performed and prior exposure history has been reviewed.

- Consider the impact of intakes on allowable external exposure for workers with internal doses.

- Consider a work restriction if the committed dose from intakes significantly impacts administrative control levels.
- Consider a temporary work restriction to avoid exposure to similar radionuclides if such exposures could adversely affect an ongoing investigation of a potential intake.
- Provide long-term follow-up bioassay measurements for workers with significant internal depositions. These measurements track the retention of the radionuclide and establish a baseline against which to evaluate possible future exposures.
- Inform the worker of the status of the follow-up investigation and dose assessment.

3.5 Reference

International Commission on Radiological Protection (ICRP). 1979. "Limits for intakes of radionuclides by workers." IICRP Publication 30, Part 1.), *Annals of the ICRP*, 2:3-4, Pergamon Press, New York.

International Commission on Radiological Protection (ICRP). 1994. "Human respiratory tract model for radiological protection.". (ICRP Publication 66), *Annals of the ICRP*, 24:1-3, Pergamon Press, New York.

International Commission on Radiological Protection (ICRP). 2002. "Doses to the embryo and fetus from intakes of radionuclides by the mother. Corrected Version, May 2002" (ICRP Publication 88), *Annals of the ICRP*, 31:1-3, Pergamon Press, New York.

Jones, S. R. 1985. "Derivation and validation of a urinary excretion function for plutonium applicable over tens of years post uptake." *Radiation Protection Dosimetry* 11(1):19-27.

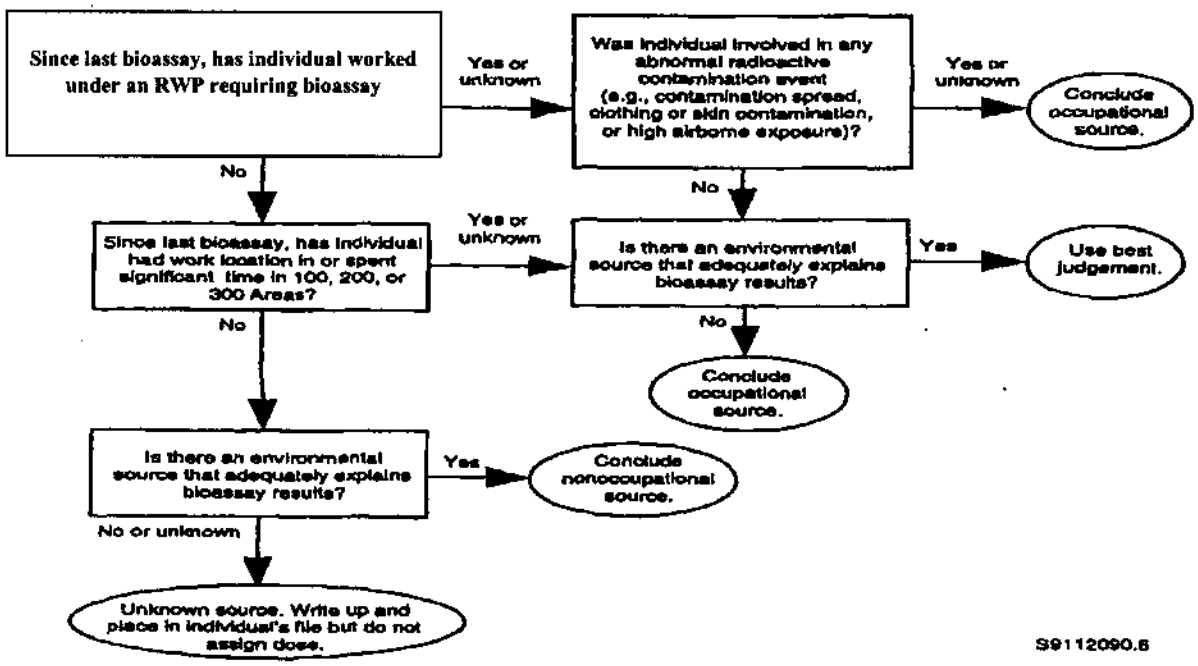
Pacific Northwest National Laboratory (PNNL). *Methods and Models of the Hanford Internal Dosimetry Program*, PNNL-MA-860. Richland, Washington. (Internal manual.) Available at URL http://www.pnl.gov/eshs/pub/pnnl860.html.

U.S. Nuclear Regulatory Commission (NRC). 1992. "Radiation Dose to the Embryo/Fetus." NRC Regulatory Guide 8.36, U.S. Government Printing Office, Washington, D.C.

EXHIBIT 3.1. Internal Dose Evaluation Report Form

Battelle Pacific Northwest Laboratories	STRICTLY PRIVATE EVALUATION OF POTENTIAL INTERNAL EXPOSURE		
Name	Payroll No.	Soc. Sec. No.	Potential Intake No.
Potential Intake Scenario:		Date of Potential Intake:	
Dose Evaluation Summary:			
Attachments:		Evaluated by: Reviewed by:	

EXHIBIT 3.2. Determining Occupational and Nonoccupational Intakes*



*Does not apply to ^{241}Am or plutonium because of possible increases over long time periods.

EXHIBIT 3.3. Baseline Samples - Tritium

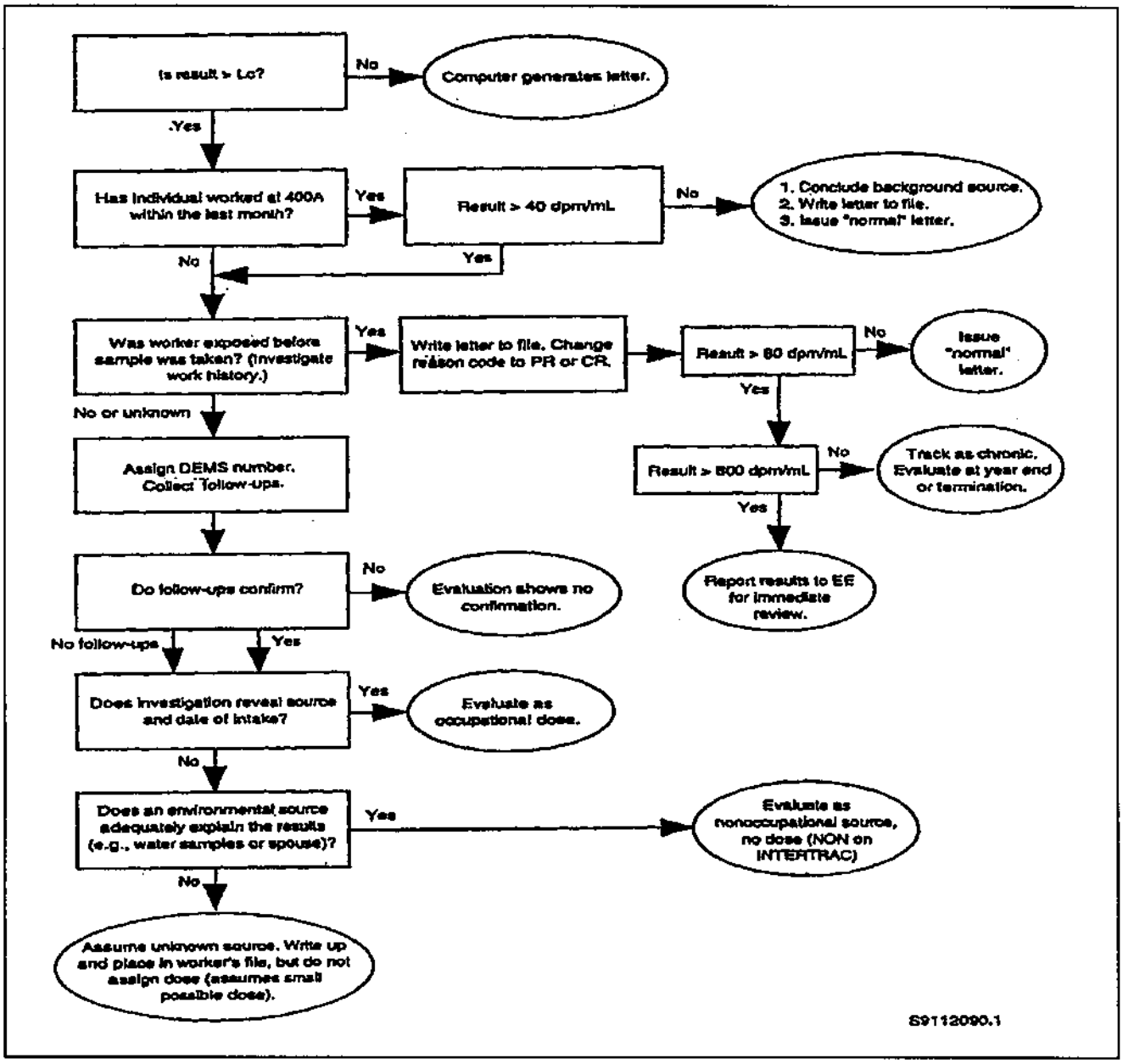


EXHIBIT 3.4. Baseline Samples - Elemental or Isotopic Uranium

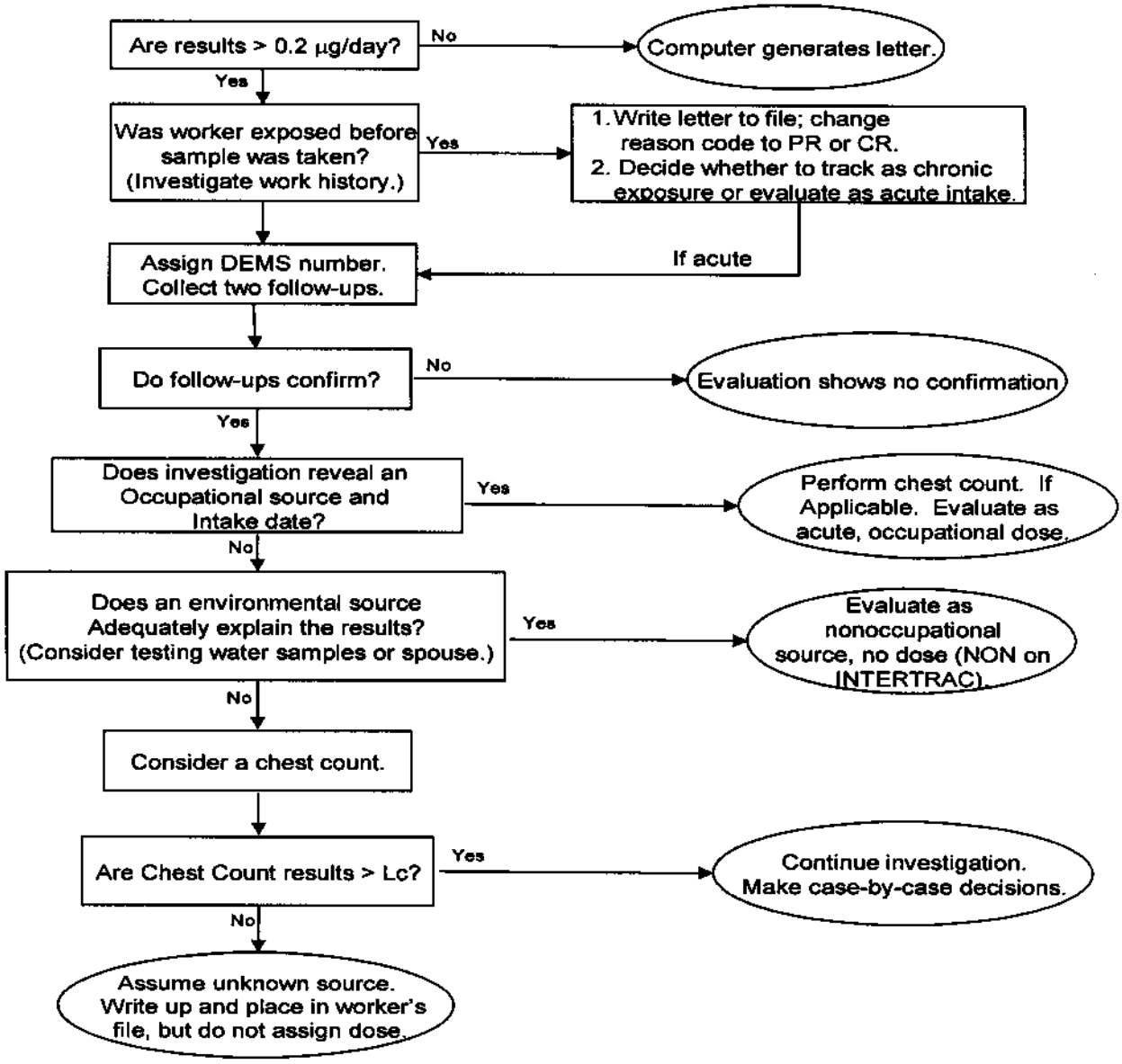


EXHIBIT 3.5. Chronic exposure assessment for soluble uranium (class D or similar) with quarterly or more frequent monitoring.

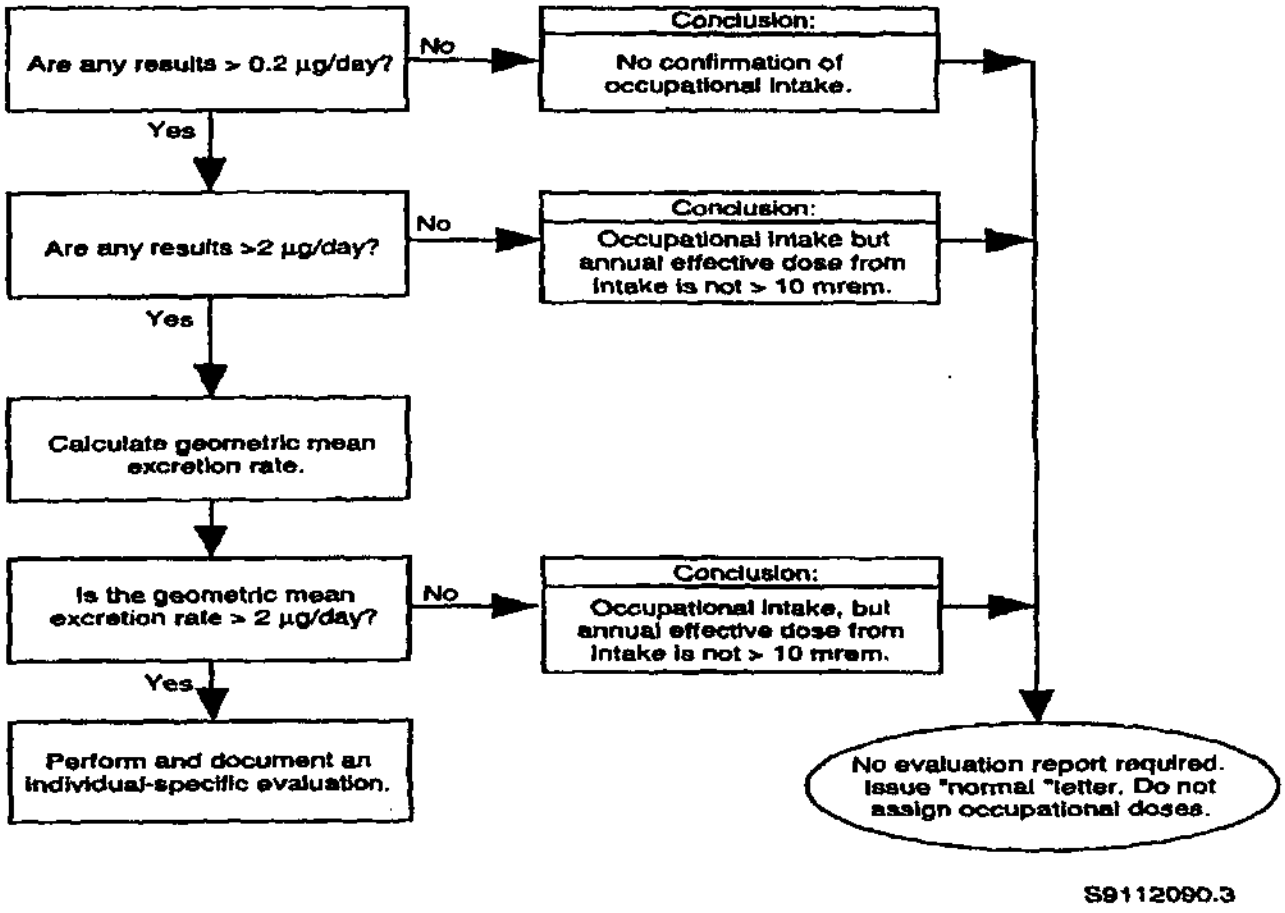


EXHIBIT 3.6. Detection of Cesium-137 in the Whole Body Exam

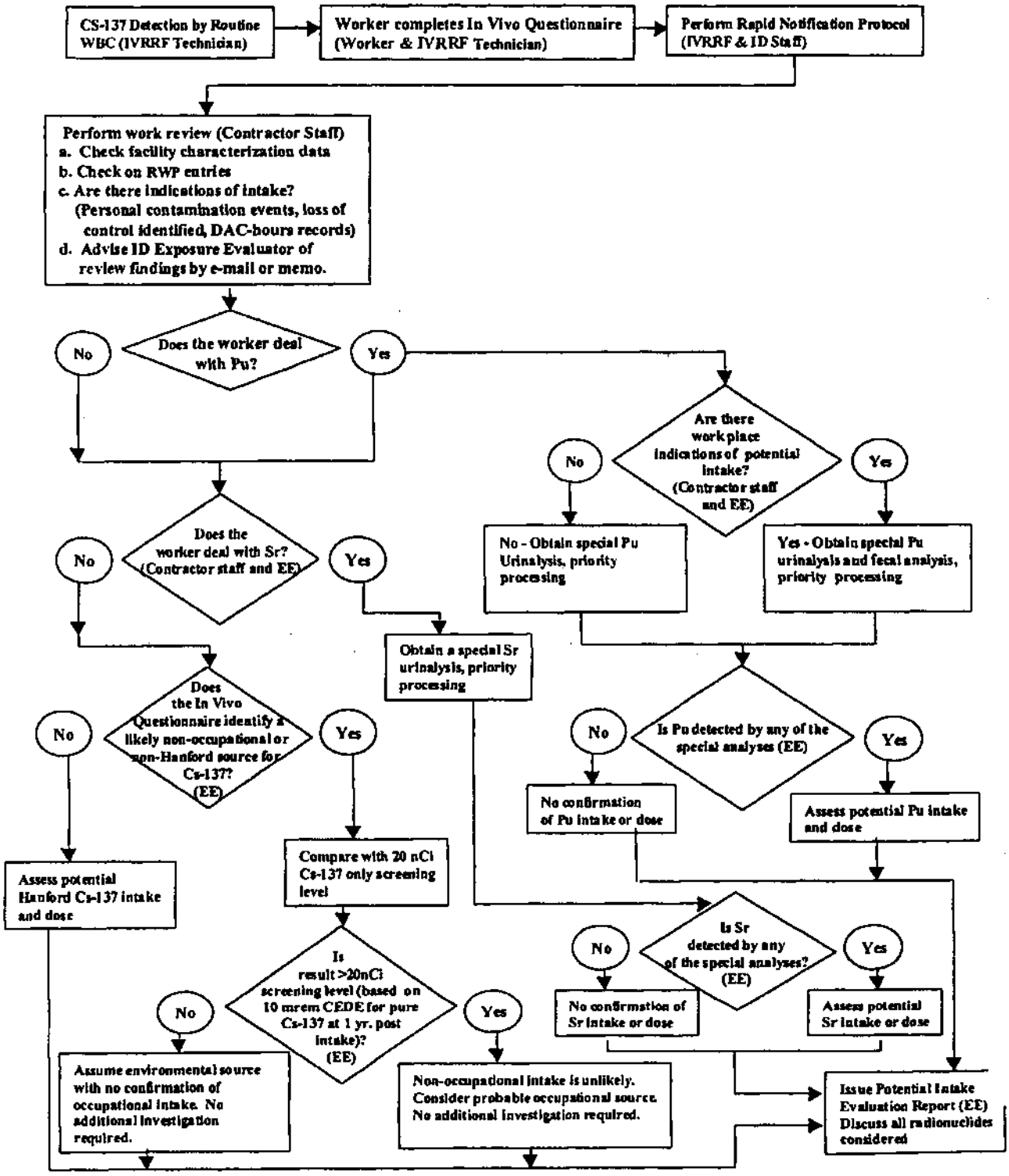


EXHIBIT 3.7. In Vivo Exam Questionnaire

IN VIVO EXAM QUESTIONNAIRE

Name: _____ Payroll No.:

Contractor: _____ Exam Date:

Your in vivo exam on the above date detected the presence of _____ Please answer the following questions to help us determine the follow-up required.

1. **Yes No** Since your exam, have you been involved in any incidents of personal contamination or potential intake?

   If YES, please briefly describe where, when, and what happened.

2. **Yes No** If you have not been involved in any incidents, have you worked with or around unsealed sources containing the radionuclide identified in your exam?

   If YES, and this work occurred at facilities other than Hanford, please indicate what facility and where it is, and when the work occurred.

3. **For Cesium-137 (^{137}Cs) Only**: This nuclide can occur naturally from some lifestyle choices.

   Yes No Do you eat wild big game (e.g., deer, elk, moose)?

   If YES, please describe:

Type of Game	Where Bagged	How Often	How Much

   Yes No Have you recently (within the last year) been in Europe, Scandinavia, Russia, Ukraine, or Byelorussia or eaten foodstuffs from those areas?

   If YES, please describe:

4. If you wish to make any additional comments that you think might be helpful in determining the source of the detected radioactivity, please note them here:

Please sign and date this form and return it to the technician who gave it to you, or mail it to Internal Dosimetry at MSIN P7-51. If you have any questions, contact your dosimetry representative.

_____

Your signature Date

EXHIBIT 3.7. In Vivo Exam Questionnaire (contd)

FOR INTERNAL DOSIMETRY USE ONLY

☐ Nonoccupational Source

☐ Below Occupational Screening Level

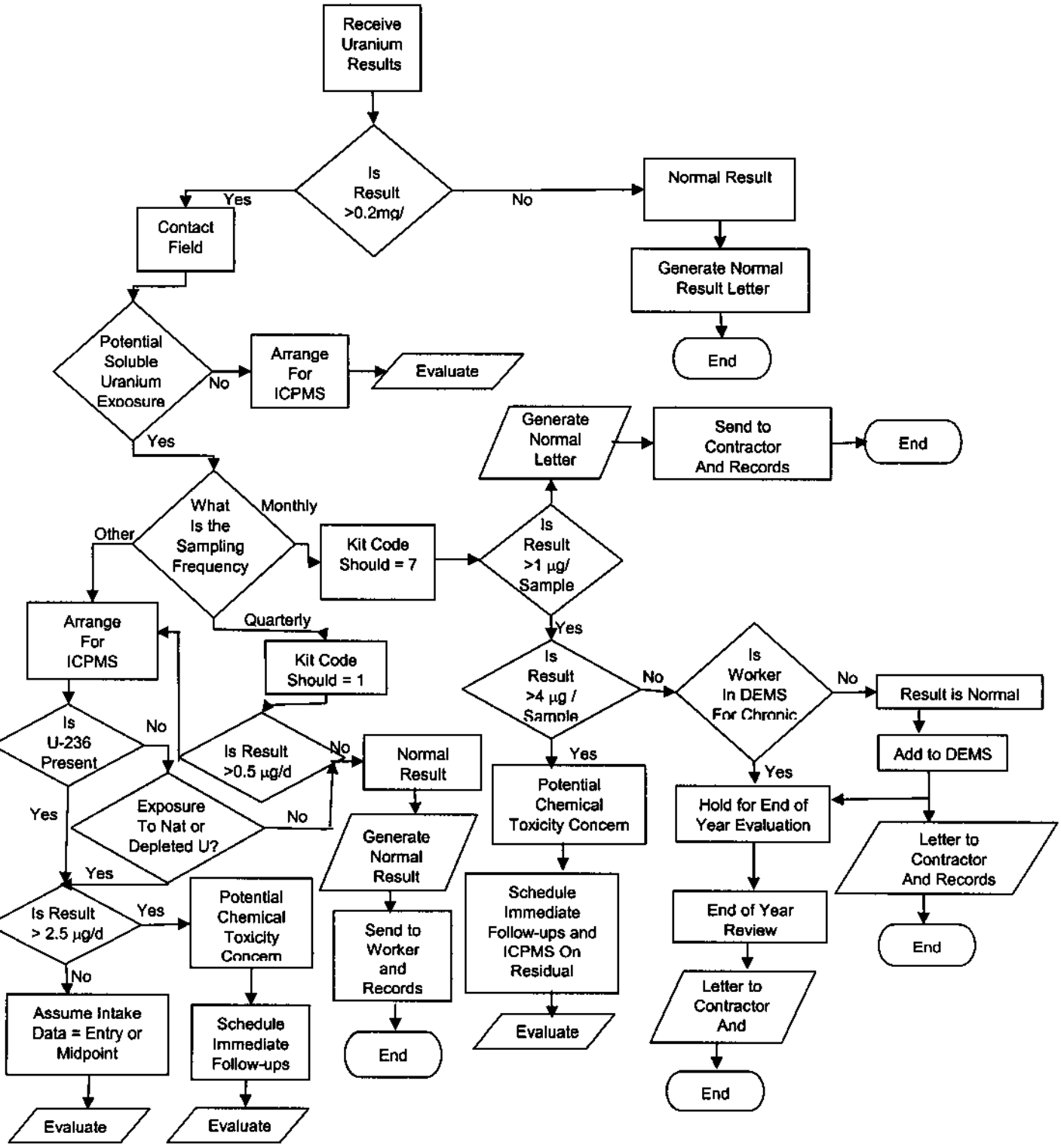
☐ Investigation Needed

Comments:

_____ _____

Internal Dosimetry Date

EXHIBIT 3.8. Review of Elemental Uranium Urinalysis Results



HANFORD INTERNAL DOSIMETRY PROGRAM MANUAL
PNL-MA-552

SECTION 4.0, RECORDING AND REPORTING INTERNAL DOSES

Issued: 12/2006

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Approved by: Eugene H Carbaugh 12/21/2006
E.H. Carbaugh, Internal Dosimetry Program Manager

Reviewer Signatures:

Reviewed by:
C.L. Antonio

Approved by the Hanford Personnel Dosimetry Advisory Committee as recorded in the meeting minutes of **November 14, 2006**.

4.0 Recording and Reporting Internal Doses

Reports of occupational dose equivalent are required as specified in 10 CFR 835, and in DOE Order 231.1A and Manual 231.1-1A. The occupational dose equivalent is composed of the dose equivalent received from external sources of radiation and the CEDE from intakes of radionuclides. This chapter describes the recording and reporting of the internal dose component, as performed by the Internal Dosimetry Program (IDP). Assessed internal doses are provided to the Hanford Radiation Records Program (HRRP). After compiling the data, the HRRP prepares the occupational dose reports.

4.1 Internal Dose Records

Evaluation Report — The primary record of internal dose is the Internal Dose Evaluation Report. Section 3.2.2 ("Documentation") describes the contents of this report, which is issued for each assessed internal exposure. Completed reports are maintained by the HRRP in the radiation exposure files.

4.2 Internal Dose Database

INTERTRAC-REX — Dose information from Internal Dose Evaluation Reports is maintained by the HRRP in the Internal Dose Tracking System (INTERTRAC) subset of the REX computer database. INTERTRAC contains committed organ and effective dose equivalent data and summary intake information from the Internal Dose Evaluation Report for each assessed intake. This information is used to generate dose summaries for tracking and reporting occupational doses to individuals. REX provides online access to recorded internal doses for all active Hanford workers. Each contractor/DOE office has access to files for its own employees.

4.3 Reports of Internal Dose

Evaluation Summary — Summary letters of assessed internal dose are issued upon completion of the Internal Dose Evaluation Report, as discussed in Section 3.2.3.

Dose Summaries — Annual occupational dose reports (i.e., report cards), reports of occupational dose for terminating employees, and reports to the DOE Radiation Exposure Monitoring System (REMS) are provided by HRRP. Special requests for internal dosimetry information may be made to the IDP.

Chronic Exposure — Some Hanford workers may be considered to be chronically exposed to radionuclides during the course of their work. Typically, these are individuals working with tritium or uranium of low or depleted enrichment. Bioassay samples for these workers are collected throughout the year. A final internal dose assessment is issued at the end of each calendar year for those workers having routine bioassay results that suggest a CEDE could exceed 10 mrem.

Throughout the year, the routine bioassay measurements are reviewed and the contractor/DOE office is advised if there is an indication that the CEDE from chronic intakes could exceed 100 mrem.

4.4 Requests for Internal Dosimetry Records

Occupational radiation exposure records are controlled according to the requirements and provisions of the Privacy Act (1974) and ANSI\HPS N13.6, *Practice for Occupational Radiation Exposure Records Systems* (HPS, 1999). Access to the records is provided through the HRRP, as follows:

- Current employees may contact their company's radiation protection representative, who will arrange to obtain the requested records.
- Individuals may request their records either in person or by mail. Verbal requests are not honored.
- Employers requesting records of current or former Hanford workers should contact the HRRP.
- Requests by the U.S. Transuranium and Uranium Registries should be made by contacting the HRRP.
- If none of the above apply or are practical, contact the DOE Privacy Act Officer, who will prepare the proper paperwork and submit the request to the HRRP.

In the above cases, the following items are required before records can be released:

- An individual appearing in person must provide a driver's license or other photographic identification and sign a release form that will be provided by the HRRP. This signed release is entered into the individual's REX record.
- An individual requesting records by mail must provide in a notarized written request his/her name, social security number and/or payroll number, and signature. This written request must define exactly which records are needed and the address to which they should be sent. Verbal requests are not honored.
- Employer and U.S. Transuranium Registry requests must be accompanied by a signed radiation exposure release-of-information form.

4.5 Reference

5 USC 552a. 1974. The Privacy Act of 1974, as amended, Public Law 93-579.

10 CFR 835. 1999. Department of Energy, *Occupational Radiation Protection.* U.S. Code of Federal Regulations.

Health Physics Society (HPS). 1999. *American National Standard Practice for Occupational Radiation Exposure Records Systems.* ANSI\HPS N13.6-1999, McLean, Virginia.

U.S. Department of Energy (DOE). 2004. "Environment, Safety and Health Reporting." DOE O 231.1A Chg 1. U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy. 2004. "Environment, Safety and Health Reporting Manual." DOE M 231.1A. U.S. Department of Energy, Washington, D.C. (available online at www.directives.doe.gov)

HANFORD INTERNAL DOSIMETRY PROGRAM MANUAL
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SECTION 5.0, BIOASSAY MONITORING

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5.0 BIOASSAY MONITORING

This chapter recommends bioassay programs for some typical applications. In addition, it discusses who should be included in a routine bioassay monitoring program, what measurements should be performed, and at what frequency.

This chapter provides recommendations and methods to implement the requirements of 10 CFR 835 (1999). Guidance in the DOE Internal Dosimetry Program Guide (2005), the DOE Standard Internal Dosimetry (1999) and ANSI Standards (HPS 1994, 1997, 2001) has been considered in providing the recommendations for participation in periodic, baseline, termination (or end-of-assignment), and special bioassay monitoring. Elaboration on the technical basis of some of these criteria is provided in the following subsections.

5.1 RECOMMENDED BIOASSAY PROGRAMS FOR TYPICAL APPLICATIONS

A summary of recommended combinations of measurements for various nuclides and situations is given in Table 5.1 for single nuclides and for some typical Hanford radionuclide combinations. This tabulation is provided as a convenience for use in a wide range of Hanford facilities, and the recommendations should meet the objectives of Section 2.3. The following sections of this chapter provide guidance and methods for designing task or facility-specific bioassay programs which may be desired as alternatives to those of Table 5.1. Optimum programs can be designed by Internal Dosimetry based on characterized sources and potential intake patterns.

5.2 MINIMUM DETECTABLE DOSE FOR BIOASSAY INTERVALS

Selected minimum detectable doses associated with various nuclides, bioassay techniques, and intervals are shown in the exhibits at the end of this chapter. For acute intakes, the analyses assume that an intake occurs on the day following a bioassay measurement and that the bioassay measurement has fallen below the MDA by the next scheduled measurement. For chronic intakes, a uniform daily intake pattern is assumed to exist for the monitoring interval. Dosimetry methods and factors are those described in the internal manual, *Methods and Models of the Hanford Internal Dosimetry Program (PNNL-MA-860),* unless otherwise noted.

TABLE 5.1 Recommended Bioassay Programs for Typical Applications

Application	Program Description
High-energy gamma emitters (e.g., ^{137}Cs, ^{60}Co, ^{154}Eu)	Annual whole body count. If activity is detected on a stand-up count, a coaxial germanium count is performed. Baseline recommended.
^{90}Sr and ^{137}Cs mixtures (^{137}Cs as an indicator for the mixture)	Annual whole body count if the Sr:Cs ratio does not exceed 20:1. Supplement with biennial ^{90}Sr urinalysis at ratios above 20:1. Use of coaxial germanium whole body counter changes ratio to 40:1.
^{137}Cs and Pu-alpha mixtures (^{137}Cs as an indicator for the mixture)	Annual whole body count supplemented by Pu urinalysis based on mixture composition.
Cs:Pu > 100:1	Annual whole body count.
Cs:Pu between 10:1 and 100:1	Annual whole body count, preferably using coaxial germanium system. Periodic program may not detect 100-mrem CEDE.
Cs:Pu < 10:1	Consider as a Pu bioassay program supplemented with an annual whole body count. (Annual Pu urinalysis, annual or biennial chest count, and annual whole body count.) Periodic program cannot detect 100-mrem CEDE.
Pu mixtures containing ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, and possibly ingrown ^{241}Am. Application to either class W or unknown class.	Annual Pu urinalysis (IPU code) for all Pu workers. Supplement with annual chest counts for high risk workers. No periodic program is adequate to detect 100-mrem CEDE. Baselines optional but strongly recommended for workers with previous potential for Pu or ^{241}Am exposure.
Pu mixtures consisting of high-fired Pu oxides	Annual Pu urinalysis (IPU analysis code) and annual chest counts.
Relatively non-transportable uranium (mixtures of uranium metal or oxides involving predominantly inhalation class W or Y forms)	Annual urine sample and chest count is adequate for acute exposure scenarios. For chronic exposure use a combination of quarterly urine samples and annual or semi-annual chest counts. No periodic program is adequate to detect 100-mrem CEDE for Class Y uranium. Baseline needed.
Readily transportable (Class D) uranium, infrequent or acute exposure	Quarterly monitoring or end-of-assignment for short duration work. Elemental (U) or isotopic (IU) analysis, as appropriate for mixture. Baseline needed.
Readily transportable (Class D) uranium, chronic exposure	Biweekly or monthly urine samples obtained after a 2-day absence from workplace (kit code 7). Elemental (U) or isotopic (IU) analysis, as appropriate for mixture.

Application	Program Description
	Baseline needed.
Tritium (tritium oxide, tritiated water)	Monthly urine samples for potential chronic or multiple acute exposure, with frequency changed to biweekly if annual tritium dose will likely exceed 100-mrem. End-of-assignment sample appropriate for infrequent or short-term (<1-month) exposure periods.
^{90}Sr (pure, i.e., without ^{137}Cs)	Annual urinalysis. Biennial urinalysis is capable of meeting the 100-mrem bioassay goal but may allow intakes to go undetected for up to two years. Baseline optional.
^{90}Sr and Pu-alpha mixtures (^{90}Sr as an indicator for the mixture)	Annual ^{90}Sr urinalysis supplemented by Pu urinalysis based on mixture composition.
Sr:Pu> 600:1	Annual ^{90}Sr urinalysis
Sr:Pu between 100:1 and 600:1	Annual ^{90}Sr urinalysis and consider plutonium urinalysis Routine program may not be able to detect 100 mrem CEDE.
Sr:Pu < 100:1	Annual ^{90}Sr urinalysis and plutonium urinalysis. Consider annual chest count. Routine program cannot detect 100 mrem CEDE.
^{131}I	Monthly whole body count or bimonthly thyroid counts.
^{129}I, ^{125}I	Annual thyroid counts
Np	The chief contributor to dose, even in high-purity Np situations, will most likely be trace quantities of Pu which can be monitored by Pu bioassay. Np bioassay may not be required. Verify the specific situation with the IDP staff.
Thorium (^{232}Th, ^{228}Th, Th-natural)	Use DAC-hours for routine dose assessment. Reliance must be placed on workplace indicators as initiators for special bioassay. Reasonable periodic bioassay is not adequate for demonstrating compliance with dose limits. Consult with IDP staff on specific situations. Baseline recommended.
Short half-life radionuclides (e.g., ^{90}Y, ^{24}Na)	Bioassay programs may not be feasible, thus reliance must be placed on workplace indicators and air sampling (DAC-hours) for exposure or intake assessment. Consult IDP staff on specific applications.

5.3 CONDITIONS FOR MONITORING WORKERS

Personnel are required by 10 CFR 835 (1999) to participate in an internal dosimetry program, including routine bioassay, if they are likely to receive intakes in a year resulting in a CEDE of 100-mrem. In addition, minors and declared pregnant workers are required to participate in such programs if they are likely to receive over 50-mrem CEDE from intakes. Monitoring programs are required by 10 CFR 835.402.(d) to be adequately sensitive to demonstrate compliance with the total dose equivalent limits of 10 CFR 835.202 [i.e., 5 rem total effective dose equivalent (TEDE) and 50 rem total organ dose equivalent (TODE), defined as the sum of deep dose equivalent for external exposures and committed dose equivalent from all intakes in a year]. The DOE Internal Dosimetry Program Guide (DOE 2005) suggests that bioassay programs should be capable of verifying doses in excess of 100-mrem CEDE. Because the TEDE and TODE includes external dose, as well as the CEDE, the principle design goal for dose assessment at Hanford is to be able to identify and confirm an intake resulting in a 100-mrem CEDE. For some circumstances (e.g., plutonium and class Y forms of uranium), this goal can be achieved only through special (non-routine) bioassay monitoring that is promptly initiated by workplace indicators. Other factors must be considered in bioassay program design, and these are addressed in the objectives listed in Section 2.3.1.

Periodic Bioassay

The IDP recommends workers to participate in periodic bioassay monitoring if one or more of the following conditions applies:

- Work requires use of a respiratory protection device for radiological protection. For this circumstance, bioassay program participation provides verification that respiratory protection was adequate.
- Work in a High Contamination Area that involves contact with or disturbance of contamination.
- Work with unencapsulated radioactive material at or exceeding the values listed in Table 5.2[a] or values derived by other methods described in this section. If such work is limited to observing, supervising from a distance, or entering the room without contacting the material, then bioassay is not required unless workplace monitoring indicates that a loss of material control occurred.
- Work with contaminated soil at or exceeding the values listed in Table 5.4[a]
- Exposure to low-level airborne activity (below posting requirements) such that the total exposure for a year would exceed 40 DAC-hours.

(a) These tables provide conservative guidance for meeting the 100-mrem criterion. Improved guidance can be determined in specific cases using case-specific source information and the methods provided in this chapter.

End-of-assignment monitoring can be used in lieu of periodic monitoring if the work period is shorter than the periodic interval.

Additional consideration for periodic bioassay programs should be given to the following:

- Knowledge of or prior experience with the work performed or the facility involved.
- Workers who are subjected to a wide range of potential internal exposure conditions.

Baseline and Termination Bioassay

The IDP also identifies the following specific circumstances under which baseline and termination bioassay monitoring are recommended:

- Baseline bioassay monitoring of personnel likely to receive intakes resulting in a CEDE greater than 100 mrem shall be conducted before they begin work that may expose them to occupational intakes. (The Hanford Radiological Control Forum has noted that "monitoring" does not necessarily mean "measuring" but may include review of the worker's exposure history.)
- Termination or end-of-assignment bioassay monitoring is required for any worker who participated in or qualified for participation in bioassay monitoring, unless it is documented in the worker's radiation exposure file that the worker was not potentially exposed to unencapsulated material in the workplace.
- if the worker has had previous intakes which might affect interpretation of current bioassay measurements.
- regardless of prior exposure, if there is potential for occupational intakes of material that may be present in bioassay measurements from naturally-occurring or non-occupational radioactive sources (e.g., uranium in urine).

Special Bioassay

Special bioassay is recommended by the IDP under any of the following conditions, unless it was caused by radon progeny (also see Table 7.1):

- Facial contamination that indicates a potential for intake.
- Nasal contamination is present.
- Air monitoring indicates the potential for intakes resulting in a CEDE exceeding 100 mrem.
- An unplanned intake is suspected for any other reason.
- Periodic or ending work results indicate an unexpected intake resulting in a CEDE of 100 mrem or more.

Special bioassay is also recommended by the IDP if skin contamination can result in an intake. The levels of skin contamination requiring special bioassay are listed in Chapter 7 (see Table 7.1).

Contractor Request

Supplemental bioassay obtained at the discretion of the contractor and for which special review or evaluation is not required. The reason for a contractor request bioassay should be documented to the worker's

personal radiation history file. Analytical results below the screening level receive a normal result form letter. Results exceeding the screening level are subject to the potential intake evaluation process.

General Recommendation Based on Committed Dose

The IDP recommends placing workers on a routine bioassay monitoring program if the CEDE from a single intake or multiple intakes in a single calendar year may exceed 100 mrem for all radionuclides.

For bioassay program planning purposes, a 100-mrem CEDE may be considered to correspond to chronic exposure for 1 year to 2% of a DAC, an acute or chronic intake equal to 2% of an ALI, and a time-integrated exposure to airborne contamination of 40 DAC-hours. Technically, this is not completely accurate, because if the DAC or ALI is based on the nonstochastic limit for a particular organ or tissue, the corresponding CEDE will be less than 100 mrem. Thus, the use of established DAC and ALI values is an acceptable practical and conservative approach.

The DAC, ALI, and DAC-hour concepts, as well as the nature of the work and the exposures, may be used to determine who should be included in a bioassay-monitoring program. The following subsections provide guidance for applying these concepts and conditions to bioassay monitoring.

5.3.1 Derived Air Concentration as a Basis for Bioassay

Long-Term Chronic Exposures

A worker should be placed on a routine bioassay program if chronic exposure to airborne radioactivity could exceed an average of 2% of the DAC. For exposures to multiple nuclides, the contribution from each significant nuclide should be considered. The DACs referred to in this manual are those contained in Appendix A of 10 CFR 835.

Short-Term Chronic Exposures

Workers exposed to short-term chronic exposures should participate in a routine bioassay monitoring program for each radionuclide to which they are exposed when the average air concentration exceeds that determined by the following formula:

$$\text{Air Concentration Implying Bioassay Monitoring} = \frac{0.02 * \text{DAC}}{f_w} \qquad (5.1)$$

where DAC is the derived air concentration listed in 10 CFR 835, and f_w is the occupancy factor determined by

$$f_w = \frac{\text{number of hours per year in airborne area}}{\text{2000 working hours per year}} \qquad (5.2)$$

5.3.2 Annual Limit on Intake as a Basis for Bioassay Monitoring

The ALI is a useful concept for bioassay planning when acute intakes are considered or exposure may be limited to readily identified quantities or sources. A routine bioassay program should be considered if an acute or chronic intake of activity corresponding to 2% of the ALI might be possible. Although ALIs are not listed in 10 CFR 835, they can be derived by multiplying the 10 CFR 835 DAC (units of μCi/ml) by 2.4E+9 (giving the ALI in units of micro curies) or by using the values in the U.S. EPA Federal Guidance Report No. 11 (EPA 1988). Even if not chronically exposed to airborne radioactivity, certain workers risk incurring an intake because of an unplanned breakdown of a protection barrier. Potential conditions may be identified by the amount of material handled in a process, the physical form of the material, and the type of containment, or by the determination that the workers frequently need respiratory protection.

One approach to the consideration of source magnitude and containment is to use potential intake factors related to material form and containment. The potential intake factors in Table 5.3 should be considered as general guidance only. Actual facility experience should be used whenever possible.

For example, a worker should be included in a routine bioassay monitoring program if the activity of an unencapsulated radionuclide that is frequently handled, processed, or worked with in any way equals or exceeds the activity calculated by the following formula:

$$\text{Activity of Material Indicating Bioassay Monitoring Required} = \frac{0.02 * \text{ALI}}{\text{potential intake fraction}} \qquad (5.3)$$

where ALI is the annual limit on intake. Some default potential intake fractions are listed in Table 5.3 as a function of the type of containment and physical form. The information in that table should be considered as general guidance only; actual facility experience should be used whenever possible. Equation 5.3 and Table 5.3 were used to prepare Table 5.2 that shows the amount of radioactive material in process that would warrant bioassay monitoring under the indicated condition.

TABLE 5.2 Amount of Radioactive In Process as a Basis for Bioassay Monitoring [a]

Type of Material[b]	Activity Requiring Bioassay (μCi) [c]		
	Bench Top	Fume Hood	Glovebox
Pu, ^{241}Am-, Pu mixtures with Am	0.1	1.0	10
Uranium, very soluble, class D [d]	300 mg	3,000 mg	30,000 mg
Uranium, moderate to insoluble, class W or Y	1	10	100
Mixed fission/activation products (based on class D ^{90}Sr)	400	4,000	40,000
Strontium-90, insoluble, class Y	80	800	8,000
Radioiodines, half-life > 1 day < 1 yr	8,000	80,000	800,000
Iodine-129	2,000	20,000	200,000
Tritium (HTO and HT) (nucleotide precursors)	10,000	100,000	1,000,000
Tritium mixed with inert H_3O or other substances.[e]	1μCi/g (1000 μci/L)	10μCi/g (10,000 μCi/L)	100μCi/g (100,000 μCi/L)

(a) Involves actual work with or contact with the material. Not intended to include occasional observation, unrelated work I the same room, or other activities involving much less risk of contamination.

(b) For other types of radioactive material, other contaminants, or unique situations, consult with Internal Dosimetry for guidance.

(c) Calculated using the method described in Section 5.3.2, assuming inhalation of 1 μm AMAD aerosol and the ALI of Federal Guidance Report No. 11 (EPA 1988).

(d) Based on 15mg intake of 1-μm AMAD particles.

(e) Derived from HPS N13.14-1994, NUREG 0938 (Brodsky 1983), and USNRC Regulatory Guide 8.32, (NRC 1988) accounting for more restrictive DOE monitoring requirements.

If a worker is exposed to more than one radionuclide, the result of Equation (5.3) should be weighted, based on the number of significant nuclides.

As an alternative to the Table 5.3 values, potential intake fractions may be calculated using the method of HPS N13.39 (2001) as shown in Exhibit 5.10.

TABLE 5.3 Potential Intake Fractions[a] as a Function of Containment Type and Physical Form

Form	Containment		
	Glovebox	Open-Faced Hood	Open Area
Tritium[b]	1.6E-4	1.6E-3	1.6E-2
Powders	1E-5	1E-4	1E-3
Volatile liquids, elevated temperatures, iodines	1E-6	1E-5	1E-4
Normal liquids	1E-7	1E-6	1E-5
Grinding, sawing, polishing, etc., on solids	1E-8	1E-7	1E-6

(a) Extrapolated from data and discussion in Watson and Fisher (1987; pp. 15-19) and from Brodsky (1980). The purpose of these potential intake fractions is to determine the need for participation in a bioassay program. The fractions should not be used to estimate actual expected releases under average conditions.

(b) Data from NRC Regulatory Guide 8.32 (1988).

5.3.3 DAC-hours Exposure as a Basis for Bioassay Monitoring

DAC-hours of airborne exposure are an indication of potential intake. Worker exposure (in terms of DAC-hours) should be expressed after appropriate correction for respiratory protection. The dose to an individual can be determined based on airborne radioactivity data according to the direction of items (a) through (g) below, but these actions are not necessary if routine bioassay monitoring can detect exposures less than 40 DAC-hours, and a policy of performing special bioassays is implemented for potential intakes resulting from unplanned incidents. For conversion to dose, DAC-hours should be first converted to a potential intake. The following actions are recommended for purposes of dosimetry:

a) A DAC-hours tracking log should be initiated for single intakes in excess of 1 DAC-hour. Single intakes below 1 DAC-hour are considered insignificant and do not require tracking.
b) Acute exposures > 40 DAC-hours should be investigated by special bioassay with a subsequent evaluation issued by the Hanford Internal Dosimetry Program.
c) Acute exposures between 10 and 40 DAC-hours should be considered for special bioassay and undergo an internal dose evaluation based on the data most appropriate for the individual, factoring in considerations for sensitivity and representativeness.

NOTE: For ^{239}Pu using the Hanford models, 1 DAC-hour (class W) will correspond to approximately 1.2 mrem CEDE

for 5-μm particles. Thus, the implied dose of 10 – 40 DAC-hours is nominally 10 to 40 mrem.)

d) Acute exposures below 10 DAC-hours need not be confirmed by bioassay for dose evaluation. At such low levels, the determination of whether bioassay or DAC-hours is most representative is highly subjective and the decision should be made by the contractor in consultation with Internal Dosimetry, based on the circumstances of each case. Bioassay is useful to provide a possible upper bound on the individual's intake and dose, although actual assessment of that upper bound is not required. However, doses may be assigned directly from DAC-hours exposure, without bioassay, if it is concluded that the DAC-hours exposure is a reasonable estimate of the worker's intake.

e) For multiple small acute exposures or chronic low-level exposures, where the cumulative exposure does not exceed 40 DAC-hours in a calendar year, doses may be assigned directly from DAC-hours estimates.

f) Cumulative DAC-hours exposures > 10 DAC-hours in a calendar year should undergo dose assessment and be included in the worker's exposure history.

g) Cumulative DAC-hours exposures ≤10 DAC-hours in a calendar year may be dispositioned at the contractor's discretion. They may be permanently recorded in the worker's files, but individual dose assessment and recording is not required. It is highly unlikely that CEDEs in excess of 10 mrem (Pu) would go unreported. The upper bound of a CEDE for ^{90}Sr or ^{137}Cs using this scheme would be 25 mrem, however workers at such levels are typically subject to more sensitive periodic bioassay measurements.

Documentation by field dosimetry of the air sample representativeness is required for inclusion in a dose assignment based on DAC-hours. Facility air samples are not always representative of air breathed. Lapel sample data may generally be considered representative or conservative. General room or facility air sample data from fixed heads must be subjectively interpreted for representativeness based on investigation of the unique aspects of the potential exposure.

5.3.4 Worker Group Monitoring

Worker group monitoring can be a suitable alternative to individual worker monitoring for working situations in which the potential for intakes is very low or doses from any intakes would be quite small. The approach is to monitor only a representative portion of the workers on a rotating basis. With this program design, it is assumed that all workers have the same risk for exposure in any period, and that a bioassay result for one worker can be taken as characteristic for the entire group.

Worker group monitoring can be used in one of two ways. First, it can be used as an expedient method of confirmatory monitoring to verify

that workers do not require an individual-specific bioassay program. Secondly, it can be used to provide data for low-level chronic exposure situations in which a combined set of bioassay data from many workers is used to assign doses to individual workers.

For confirmatory monitoring, not all workers in the group need to receive bioassay. Consistent with recommendations of the NCRP (1987), the following guidance is offered for establishing the scope of a bioassay monitoring program for a group:

Worker Population	Number Monitored
≥120	10%
12 to 120	12
<12	All

If a screening level applied to a worker group is exceeded and an intake is confirmed, then all members of the group should be placed on individual bioassay programs, unless an investigation shows that just the one worker was exposed due to unusual circumstances.

5.3.5 Environmental Restoration and Remediation Activities

Special criteria have been developed for application to environmental restoration and remediation (ER) work at Hanford. This work may involve short-term soil sampling activities, excavation of dirt, transport of contaminated soil, or sample well or monitoring borehole drilling operations. The soil involved may range from essentially uncontaminated overburden at burial grounds to soil contaminated with a wide range and magnitude of radionuclides at liquid effluent disposal sites, such as cribs or ponds.

Criteria for two types of exposure conditions have been addressed: the single job involving acute exposure to very high dust loadings in air (i.e., near the worker tolerance level for dust), and the long-term job involving chronic exposure to moderately high dust loadings. The acute exposure assumed a 360-mg inhalation intake (e.g., 2 hours exposure to 150-mg/m^3 dust loading) of 1-μm-AMAD dust. The chronic exposure assumed an inhalation intake rate of 48 mg/day of 1-μm-AMAD dust for 250 working days/year (e.g., 2-h/day exposure to a 20-mg/m^3 dust loading.

Soil contamination criteria are shown in Table 5.4. As long as the geometric mean soil concentrations do not exceed those listed, worker bioassay measurements are not required. Use of the arithmetic mean soil concentration (as a convenient substitute for the geometric mean) is acceptable, and will result in conservative determinations of the need for bioassay. The soil concentration values shown are for the most restrictive inhalation class considered likely to be encountered.

TABLE 5.4 Bioassay Monitoring Criteria for Work Involving Exposure to Contaminated Soil[(a)]

Nuclide, Form[b]	Soil Contamination (pCi/g)[c] Acute[d]	Chronic[e]
Uranium - Total[f]		
class D or W	40,000	1,000
class Y	3,000	70
Pu-α class W	400	20
Th-232 class W	60	2
Th-228 class W	600	20
Sr-90 class D	1,000,000	40,000
Cs-137 class D	20,000,000	400,000
Co-60 class Y	2,000,000	50,000
Tritium in groundwater[g]	5,000 μCi/L	1,000 μCi/L

(a) Criteria are established for two potential scenarios. "Acute" implies normally not exposed to contamination but potential exists for a single, heavy exposure. "Chronic" implies frequent exposure to less dusty conditions. Bioassay would be required if either scenario applied to a worker.

(b) For other nuclides or chemical forms, consult with Internal Dosimetry for guidance.

(c) Units apply to uniform concentrations representative of the soil being disturbed, and not to small, spotty contamination.

(d) Assumes a 360-mg inhalation intake of 1-μm AMAD soil dust in a single exposure.

(e) Assumes a 48-mg/day inhalation intake rate of 1-μm AMAD soil dust particles for 250 working days/year.

(f) U-natural, ^{234}U, ^{235}U, or ^{238}U in any combination. Based on recycled uranium common at Hanford. Same numbers apply for uranium in units of ppm or μg/g soil.

(g) Assumes consumption of one cup (acute) or one cup per day of groundwater at the indicated contamination.

In addition, based on the highest measured tritium contamination levels in Hanford groundwater, there is no need for workers to be on a tritium bioassay program. Tritium bioassay for ER work need not be considered unless concentrations in water exceed 1000 μCi/L.

Exposure to multiple radionuclides must address the additive impact of all nuclides. The need for bioassay can then be established by calculating an "index for bioassay" value as the sum of the ratios of each nuclide to its respective criterion value, as shown below:

$$\text{Index for Bioassay} = \frac{\text{conc.1}}{\text{criteria 1}} + \frac{\text{conc.2}}{\text{criteria 2}} + \text{etc.}$$

If the index value exceeds one, a bioassay program should be established. The issue of what type of bioassay to perform remains. Where sources consist of a single contaminant, the choice is generally obvious. If multiple contaminants are involved, the predominant nuclide may be the best choice. However, some bioassay procedures are substantially more sensitive than others, and if one nuclide can be

used as an indicator for another (because of known source inter-relationships), then a more sensitive bioassay procedure for a less predominant radionuclide may be adequate. IDP staff can be consulted for advice on specific situations. Further details on these criteria are provided in the supporting report.[a]

5.3.6 Long-Term Follow-Up of a Prior Deposition

A worker who has been assessed as having a long-term internal deposition of radioactive material may be recommended by Internal Dosimetry for a specialized follow-up bioassay monitoring program to verify the accuracy of the assessment and identify any potential need for revision. This provision results from the need to update long-term body burdens and associated doses from well-retained radionuclides, and should apply regardless of present work assignment or origin of the occupational exposure.

Better understanding of the biokinetic behavior of retained material and improved estimates of dose can be obtained from long-term follow-up bioassay measurements. For example, a small, very long-term component of material in the lung may be masked for several years by short-term components until the short-term components are removed. However, the long-term component may add significantly to the 50-year committed dose.

Long-term follow-up monitoring is most likely to be associated with depositions of plutonium and americium, although other nuclides may also warrant it.

5.3.7 Baseline and Ending Work Bioassay

Baseline (or contractor request) and end-of-assignment samples or measurements should be obtained for a worker whose work assignments will require, or have required, routine bioassay monitoring (NCRP 1987; HPS 1997). Such samples should provide a better estimate of the time and nature of an intake, prevent the improper assignment of a prior intake to the present task, and provide accurate feedback on the effectiveness of radiation protection measures for specific work assignments.

Baseline and end-of-assignment measurements may be a suitable alternative to the routine bioassay monitoring associated with work assignments of limited duration. Consult with Internal Dosimetry to determine whether this option is appropriate.

End-of-assignment measurements may be performed in lieu of and at the scheduled time of routine measurements. This option does not apply to visitors and terminating employees who should have specially

(a) Letter report to T. J. Kelly (WHC) from Eugene H. Carbaugh (PNL) dated December 3, 1991, "Bioassay Criteria for Environmental Restoration Workers." A copy is maintained in the permanent files of the Hanford Radiological Records Program.

scheduled measurements.

5.3.8 Offsite Intake Monitoring

Bioassay programs designed for monitoring intakes and work at Hanford may not necessarily be adequate for monitoring at offsite facilities. Internal Dosimetry should be contacted to determine the appropriate bioassay if offsite intake is a possibility.

5.3.9 Visitors and Minors

Routine bioassay programs for plutonium, thorium, and insoluble uranium are not capable of demonstrating compliance with the 100-mrem CEDE limit for minors and visitors. Therefore, it is recommended that RWPs prohibit minors and visitors from being exposed to these materials such that they would be at risk for an intake which could exceed the 100-mrem CEDE limit. If there is potential for external dose as well, then the potential intake must be at a level less than 100 mrem to assure that the TEDE doesn't exceed 100 mrem. If necessary, fecal sampling performed immediately after an acute or short-term exposure can demonstrate compliance with the limit.

Bioassay monitoring is required by 10 CFR 835 if it is likely that visitors or minors will receive over 50-mrem CEDE from an intake. Although monitoring may be required, as noted in the preceding paragraph, there are nuclides for which routine monitoring is not capable of demonstrating compliance with the dose limits. For purposes of determining the need for bioassay, the radioactive material levels in Tables 5.2 and 5.3 are adequate to meet the 50-mrem criteria for visitors and minors, as well as the 100-mrem criteria for radiological workers.

Special bioassays will be performed if conditions encountered while at Hanford require them. If measurements are performed at the beginning or end of the visit, any abnormal results will be reported to the responsible Hanford contractor. Internal doses for detectable baseline results will be assessed only if a specific request is made by the contractor.

5.3.10 Declared Pregnancy

The 10 CFR 835 dose limit for declared pregnant women is substantially more restrictive than for occupational workers.

When a worker on a routine bioassay schedule declares her pregnancy, IDP should be notified and supplemental bioassay obtained as soon as possible. This is necessary to determine the possible internal dose to the fetus from conception to the date of declaration. These supplemental measurements should be scheduled as Contractor Requests (CR) with priority processing and include a note or comment that the measurement is pregnancy-related.

If the worker continues to be exposed to possible intakes, the contractor must schedule another bioassay measurement at the conclusion of the pregnancy. The same scheduling protocol should be used. The minimum detectable doses for embryo-fetus bioassay programs are shown in Exhibit 5.8. Doses to the embryo-fetus are based on the gestation period dose and not the CEDE.

The 10-mrem screening levels of Appendix A will be used as a basis for determining the need for evaluation.

5.4 SELECTION OF NUCLIDES FOR BIOASSAY

Any radionuclide or mixture of radionuclides that may contribute more than 25% to the 100-mrem committed effective dose equivalent criterion should be included in the bioassay monitoring program.

As a rule of thumb, it may be assumed that workers are not likely to be exposed to more than four reference mixtures of radionuclides. Radionuclides do not require specific bioassay monitoring if they are adequately monitored by indicator nuclides for a reference mixture. In some cases, it is possible to use indicator radionuclides for established mixtures to optimize the number of bioassay measurements performed. For example, mixtures containing ^{90}Sr and ^{137}Cs may be sufficiently monitored by using whole body measurements of ^{137}Cs as an indicator of exposure. (See Table 5.1 for guidance.)

Once a worker is placed on a routine program, that program should be reviewed on a regular basis to ensure that potentially significant nuclides are adequately addressed.

A "broad-base" bioassay program involving multiple analyses may be appropriate for workers who rotate between facilities on occasional or short-notice assignments. Such a program is intended to satisfy current baseline requirements for many facilities, rather than imply a worker is likely to incur intakes individually or collectively totaling 100-mrem CEDE.

5.5 BIOASSAY MEASUREMENT FREQUENCY

The frequency of bioassay measurements is dictated by two objectives. The first is to assure that significant acute intakes are detected for dose evaluation and appropriate corrections to the working conditions (NCRP 1987). The second is to monitor the accumulation of radioactive material in the body from low-level chronic intakes.

In general, significant acute intakes are discovered by workplace monitoring (e.g., air monitoring, and clothing and body surveys) and are investigated according to the protocol discussed in Chapter 7.0. Nevertheless, a properly chosen bioassay frequency is important both

to account for undetected, acute intakes and to monitor the effectiveness of workplace monitoring.

The choice of frequency depends on the following:

- the purpose of the measurement (i.e., to monitor for accumulation from chronic intakes, for potential acute intakes undetected by first-line monitoring methods, or for acute intakes that occur simultaneously with a known chronic intake).
- the ability to meet the 100-mrem CEDE objective stated in Section 2.3.
- MDAs for various radionuclides and bioassay measurements.
- the likelihood and ratios of combinations of radionuclides associated with an intake for a particular facility or task the cost of bioassay measurements and the cost of lost productive time while workers are participating in the bioassay program.

Longest Interval Between Bioassays

Generally, annual measurements are suggested as a convenient minimum frequency to match annual reporting requirements for worker doses. Routine bioassay measurement periods longer than five effective half-lives are also generally not recommended, because the potential deviation of individuals from assumed retention or excretion patterns can substantially affect doses associated with the program design.

For mixtures of nuclides (e.g., ^{90}Sr and ^{137}Cs), an annual individual bioassay measurement (e.g., whole body count) may be used in combination with a less frequent radionuclide-specific measurement (e.g., biennial ^{90}Sr urine sample analysis.

5.6 TECHNICAL DISCUSSION FOR RECOMMENDED PROGRAMS

The recommended bioassay programs of Table 5.1 were established based on considerations discussed below and in the exhibits at the end of this section. Additional discussion of capabilities is contained in the internal manual, *Methods and Models of the Hanford Internal Dosimetry Program,* (PNNL-MA-860).

5.6.1 Plutonium Mixtures

Baseline urine and chest measurements for plutonium and americium are not considered essential for routine monitoring of previously unexposed workers because background levels in people are far below the routine measurement detection capability. However, baselines are strongly recommended when the person has previously worked in a plutonium facility or has had a known intake of plutonium or americium.

Periodic programs are not capable of meeting the 100-mrem CEDE bioassay goal. Annual urine sampling is recommended for all Pu workers. Workers with the highest risk for Pu intake should also receive annual chest counts. Legacy dry Pu contamination in facilities

should be considered Class Y regardless of original form.

Prompt detection of an intake by use of workplace indicators is essential to provide capability to detect 100 mrem CEDE by timely initiation of special bioassay monitoring. Special monitoring should emphasize early fecal samples analyzed for isotopic Pu (IPU code) or Pu and ^{241}Am (IPA code) to provide maximum sensitivity to detection of intakes. Special Pu urinalysis, though less sensitive to intake detection than fecal sampling, is very important to help discriminate between class W and class Y forms of Pu.

Very high sensitivity mass measurements of plutonium in urine can be obtained by special arrangement with other national laboratories. These methods include thermal ionization mass spectrometry (TIMS) at Los Alamos National Laboratory and accelerator mass spectrometry (AMS) at Lawrence Livermore National Laboratory. These methods are substantially more sensitive than standard alpha spectrometry, but require special interlab arrangements and would probably involve lengthy turnaround times. They are best suited as supplemental measurements for investigations of suspected highly insoluble forms of plutonium.

5.6.2 Uranium Mixtures

Monitoring for uranium poses special problems for the following reasons:

- Uranium presents both chemical and radiological toxicity risks, the relative importance of which depends on its transportability from the lung.
- Uranium can exist in mixed transportability classes.
- Small, recent intakes easily mask larger, older intakes because nearly 50% of the uranium going to blood is cleared immediately through the urine.
- An intake of class Y material potentially resulting in a CEDE of 100 mrem generally cannot be detected by routine bioassay monitoring. Monitoring of the workplace to document the working environment and to provide immediate indication of an intake is essential.
- Low-level chronic intakes are possible for certain types of work, so the bioassay program may need to monitor for long-term buildup as well as for potentially significant acute intakes.
- Individual and temporal variability in the environmental background of uranium complicates interpretation of urinalysis results.
- Baseline urine bioassay is needed because of the highly variable nature of background excretion from individuals.

Consequently, the proper bioassay monitoring program for uranium workers is best determined on a case-by-case basis in consultation with Internal Dosimetry.

5.6.3 Strontium-Cesium Mixtures Bioassay

Mixtures of ^{90}Sr and ^{137}Cs are not uncommon at Hanford and may be found in facilities associated with fission product waste management. The composition of these mixtures can vary from essentially pure ^{90}Sr to essentially pure ^{137}Cs. Where the composition can be well-characterized, e.g., a potential intake identified at the time by field indicators, then whole body counting of ^{137}Cs may be adequate for intake assessment if a smear sample can be analyzed for the ^{90}Sr:^{137}Cs ratio.

In other circumstances, notably a high-routine whole body exam, there may not be any obvious specific material to which the worker might have been exposed. For many years 1:1 ratio was assumed based on the typical fission product yields. However, the wide range of waste management practices which have occurred at Hanford do not provide assurance that the 1:1 ratio is valid. Thus, for high-routine whole body exams, a recommended follow-up practice is to include a ^{90}Sr urinalysis unless it is clear that the worker could only have been exposed to pure ^{137}Cs or the dose consequences are quite small. The ^{90}Sr urinalysis can also help distinguish between environmental and occupational exposures of ^{137}Cs.

The issue of when to place a worker on both a whole body exam and using the ^{90}Sr urinalysis is slightly more complex. The minimum detectable doses associated with ^{137}Cs and ^{90}Sr urinalysis bioassay minimum detectable activities for several ^{90}Sr:^{137}Cs ratios are shown in Exhibit 5.6. Based on this table, an annual whole body exam using the stand-up counter is capable of meeting the 100-mrem CEDE bioassay goal for minimum detectable dose for mixtures up to about a 20:1 ^{90}Sr:^{137}Cs ratio. Supplemental ^{90}Sr urinalysis is recommended when the ^{90}Sr:^{137}Cs ratio exceeds 20:1.

5.6.4 Cesium-Plutonium Mixtures

Mixtures of ^{137}Cs and Pu may be found at Hanford in facilities associated with fuel irradiation, storage or handling of irradiated fuel, and wastes associated with such facilities. Examples include spent fuel basins, fuel processing hot cells, and waste tank sludges. By radioactivity, these mixtures are likely to be mostly ^{137}Cs, with Cs:Pu ratios ranging from perhaps 1000:1 to 1:1. Until the mid-1990s, little attention was given to trace amounts of Pu in predominantly Cs contamination. However, a recognition of the dosimetric importance of the trace Pu has developed with the implementation of the committed dose system and as more detailed facility contamination characterization data have become available.

Where the composition can be well-characterized, e.g., a potential intake identified at the time by field indicators, then whole body counting of ^{137}Cs may be adequate for intake assessment if a representative sample can be analyzed for the ^{137}Cs:Pu ratio. Such a

sample might be a nasal smear or surface wipe of the contamination.

In other circumstances, notably a high-routine whole body exam, there may not be any obvious specific material to which the worker might have been exposed. The assumption of any kind of default Cs:Pu ratio is premature at this time, and this renders difficult the investigation of high routine ^{137}Cs whole body counts for workers in those facilities.

To help determine appropriate bioassay monitoring for workers in facilities with Cs-Pu mixtures, the information in Exhibit 5.7 led to the guidelines below. For convenience, it is considered irrelevant as to whether the Pu is ^{239}Pu, ^{238}Pu, or Pu-alpha: the isotopic differences are relatively small compared to the issue of class W or Y forms and the general uncertainty of Cs:Pu ratio.

Cs:Pu >100:1

Annual ^{137}Cs whole body counting using either the stand-up counter or the coax counter is capable of meeting the 100 mrem CEDE bioassay goal. This applies to either class W or class Y forms of Pu.

Between 100:1 and 10:1

Between Cs:Pu ratios of 10:1 and about 100:1, annual ^{137}Cs whole body counting using the coaxial germanium detector system is preferred over the stand-up counter. At about the 50:1 ratio, the coax system can meet the 100-mrem CEDE bioassay goal. Both easily demonstrate compliance with the 10 CFR 835 dose limits. However, as the ratio decreases, a technical shortfall in the ability to meet the 100-mrem goal exists

Cs:Pu < 10:1

Below 10:1 the ability of whole body counting to provide adequate bioassay is weak, and the worker should be placed on a plutonium bioassay program supplemented by an annual whole body count.

High Routines

Investigation of high routine whole body counts that detect ^{137}Cs should consider the possibility of plutonium if the worker is associated with facilities having Cs-Pu mixtures. For such workers, investigation should include plutonium urinalysis as a minimum. Assuming a Pu intake had occurred within approximately the past year, the urine sample can be used to demonstrate regulatory compliance with 10 CFR 835 dose limits. Fecal samples can demonstrate compliance for class Y material (MDD of 300 to 400 mrem CEDE). If neither the urine nor fecal sample detect Pu, a dose assessment can be performed assuming ^{137}Cs alone, with the recognition that the worker has been evaluated against the MDDs for routine Pu bioassay, and has demonstrated a margin of safety comparable to plutonium workers with regard to the dose limits.

5.6.5 Strontium-Plutonium Mixtures

Strontium and plutonium mixtures can be found in such waste sources as tank farm or spent fuel storage basin sludges. Exhibit 5.7 provides

	additional details on the capability of screening measurements.
Sr:Pu >600:1	Annual ^{90}Sr urinalysis provides capability of detecting CEDE of 100 mrem or less.
Sr:Pu between 600:1 and	Annual ^{90}Sr urinalysis provided nominal minimum detectable CEDE of 100 to 500 mrem. Consider annual Pu Urinalysis as a supplement.
Sr:Pu < 100:1	The ability to use ^{90}Sr as an indicator for Pu is weak. The worker should be placed on a Pu bioassay program supplemented with annual ^{90}Sr urinalysis.

5.6.6 Special Forms of Nuclides

Special forms of radionuclides (e.g., tritium or ^{14}C-labeled materials) can behave much differently than the normal compounds for which routine bioassay programs are designed. Case-specific bioassay monitoring programs for situations such as these should be established through consultation with Internal Dosimetry.

5.7 REFERENCES

10 CFR 835. 1999. Department of Energy, *Occupational Radiation Protection.* U.S. Code of Federal Regulations.

Brodsky, A. 1980. "Resuspension factors and probabilities of intake for Material in Process, or Is 10^{-6} a Magic Number in Health Physics?" *Health Physics* 39(6):992-1000.

Brodsky, Alan. 1983. *Information for Establishing Bioassay Measurements and Evaluations of Tritium Exposure.* NUREG-0938. U.S. Nuclear Regulatory Commission. Washington, D. C.

Health Physics Society (HPS). 1994. *Internal Dosimetry Programs for Tritium Exposure – Minimum Requirements.* HPS N13.14-1994. An American National Standard approved by American National Standards Institute, Health Physics Society, McLean, Virginia.

Health Physics Society (HPS). 1997. Internal Dosimetry for Mixed Fission and Activation Products. HPS N 13.42-1997. Standard approved by American National Standards Institute, Health Physics Society, McLean, Virginia.

Health Physics Society (HPS). 2001. *Design of Internal Dosimetry Programs.* ANSI/HPS N13.39-2001. An American National Standard approved by American National Standards Institute, Health Physics Society, McLean, Virginia.

National Council on Radiation Protection and Measurements (NCRP). 1987. *Use of Bioassay Procedures for Assessment of Internal Radionuclide Deposition.* NCRP Report No. 87. Bethesda, Maryland.

Pacific Northwest National Laboratory (PNNL). *Methods and Models of the Hanford Internal Dosimetry Program,* PNNL-MA-860. Richland, Washington. (Internal manual.) Available at URL http://www.pnl.gov/eshs/pub/pnnl860.html.

U.S. Department of Energy (DOE). 1999. *DOE Standard Internal Dosimetry.* DOE-STD-1121-98. Washington, D.C. Available online at URL http://www.directives.doe.gov.

U.S. Department of Energy (DOE). 2005. *Internal Dosimetry Program Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection.* DOE G 44.1.-3A. Washington , D.C. Available online at URL http://www.directives.doc.gov.

U.S. Environmental Protection Agency (EPA). 1988. *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion.* Federal Guidance Report No. 11, EPA-520/1-88-020,. Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988. *Criteria for Establishing a Tritium Bioassay Program.* Regulatory Guide 8.32. Washington, D.C.

Watson, E.C., and D.R. Fisher. 1987. Feasibility Study on a Data-Based System for Decisions Regarding Occupational Radiation Protection Measures. NUREG/CR-48567, PNL-6137, Pacific Northwest Laboratory, Richland, Washington.

EXHIBIT 5.1

BIOASSAY CAPABILITY FOR TRITIUM

Urine Bioassay Analysis

Tritium (H3) MDA: 20 dpm/mL

The tritium monitoring program is based on liquid scintillation analysis for tritium oxide in urine. Because only 1 mL is analyzed, virtually any volume of sample can be used. For convenience, single void or simulated 12-hr samples are generally collected and a small aliquot analyzed. Program capability is shown below.

Minimum Detectable Effective Dose Equivalent (CEDE) for Acute and Chronic (365 d/y) Exposures to Tritium Oxide

Days Post-Intake or Interval Length	Single Acute Exposure (mrem)	Multiple[a] Acute Exposure (mrem)	Chronic Exposure[b] (mrem)
1	0.027	NA	0.64
2	0.029	NA	0.64
7	0.041	2.1	0.64
14	0.066	1.7	0.64
30	0.20	2.4	0.64
60	1.6	9.7	0.64
90	13	52	0.64
180	6,600(NA)	(NA)	0.64
365	NA	NA	0.64

(a) Assuming one intake per interval.
(b) Assumed constant equilibrium in body water at 20 dpm/mL.
NA = Not Applicable

EXHIBIT 5.2

IN VIVO BIOASSAY CAPABILITY FOR HIGH-ENERGY GAMMA EMITTERS

Whole Body Counting

Bioassay measurements for high-energy gamma-emitting radionuclides are performed using the IVRRF preview counter, or other systems of comparable or better sensitivity (e.g., coaxial germanium whole body counter, remote whole body counter). The minimum detectable doses for single nuclides or selected mixtures of mixed fission or activation products based on single nuclide measurement are shown below for the chemical forms commonly encountered at Hanford.

Minimum Detectable CEDEs for Single Acute 5-μm AMAD Inhalation Intake Based on MDA Detection in Preview Counter at the Indicated Day Post-Intake

Nuclide	Class	MDA[(a)] (nCi)	DPI[(b)]	Measurement Interval	CEDE (mrem)[(c)]
^{60}Co	Y	1.6	365	Annual	3.5
^{137}Cs	D	1.7	365	Annual	0.98
			730	Biennial[(d)]	9.8
^{154}Eu + ^{155}Eu[(e)]	W	7.0 (of ^{154}Eu)	365	Annual	22

(a) MDA = minimum detectable activity.
(b) DPI = day post-intake.
(c) Assumes inhalation of 5-μm AMAD aerosol.
(d) Not recommended.
(e) Assumes that the activity ratio for ^{154}Eu:^{155}Eu is 4.7:1 at times of intake, based on 20 years of decay following operating N-Reactor equilibrium condition of 2:1.

EXHIBIT 5.2 IN VIVO BIOASSAY CAPABILITY FOR HIGH-ENERGY GAMMA EMITTERS (contd)

Thyroid Counting for Radioiodine

Thyroid counting for ^{125}I and ^{129}I is the recommended bioassay over urine sample analysis for those nuclides. Thyroid counting for ^{131}I is significantly more sensitive than whole body counting for that nuclide. Thyroid counts are performed with planar germanium detectors. The program capability for thyroid counting is shown below:

Minimum Detectable CEDEs for Single Acute 5-μm AMAD Inhalation Class D Intake Based on MDA Detection in Thyroid Counter at the Indicated Day Post.Intake

Nuclide	MDA (nCi)	Day Post-Intake	Measurement Interval	CEDE (mrem)
^{125}I	0.8	30	Monthly	0.16
		90	Quarterly	0.47
		180	Semiannual	2.3
		365	Annual[(a)]	60
^{129}I	0.8	30	Monthly	0.80
		90	Quarterly	1.2
		180	Semiannual	2.0
		365	Annual[(a)]	6.3
^{131}I	0.1	30	Monthly	0.25
		60	Bimonthly	3.8
		90	Quarterly	54

(a) Recommended frequency supplemented by workplace screening using portable survey meter with NaI detector.

EXHIBIT 5.3

BIOASSAY CAPABILITY FOR STRONTIUM

Strontium-90 Bioassay Monitoring

Urine sample analysis is the preferred method for ^{90}Sr bioassay monitoring. For low-risk potential exposure situations, it may be convenient to use an annual whole body exam to monitor for ^{137}Cs as an indicator for the presence of ^{90}Sr. Program capabilities are shown below for pure ^{90}Sr. See Exhibit 5.6 for mixtures of ^{90}Sr and ^{137}Cs.

Minimum Detectable CEDEs for Single Acute 5-μm AMAD Inhalation Class D Intake Based on MDA Detection (10 dpm/d) in Urine at the Indicated Day Post-Intake

Day Post-Intake	Measurement Interval	CEDE (mrem)
1	Special	0.02
7	Special	0.07
30	Monthly	1.8
90	Quarterly	8.1
180	Semiannual	13
365	Annual[(a)]	26
730	Biennial	61

(a) Recommended frequency.

EXHIBIT 5.4

BIOASSAY CAPABILITY FOR URANIUM

Urine Bioassay Analyses

Elemental Uranium (U) MDA: 0.06 μg

Used for natural, depleted, or recycled uranium mixtures, in any chemical form. Simulated 24-hour sample collected. A screening level of 0.2 μg/d is used as an upper range of the normal expected excretion rate, implying an occupationally attributable excretion rate of 0.18 μg/d may exist above the geometric mean environmental level of 0.02 μg/d, established for the Hanford work force. Minimum detectable dose analyses for natural uranium mixtures and various intake scenarios are shown in Tables IV.1 through IV.4.

Isotopic Uranium (IU) MDA: 0.02 dpm

Used for single isotopes of uranium or mixtures enriched to greater than 5% (by weight) of ^{235}U. Simulated 24-hour sample collected. Screening levels of 0.16 and 0.15 dpm are used for $^{233+234}U$ and ^{238}U, respectively and 0.007 dpm for ^{235}U, corresponding to 0.2 μg/d for natural uranium; thus, the minimum detectable dose analyses for uranium mixtures are comparable to those for the elemental uranium procedure.

In Vivo Measurements

	Chest Count (3000 s)	Implied Uranium Present (nCi of uranium mixture)		
Isotope	MDA	Natural U	Depleted U	Recycled U
^{235}U	0.20 nCi	8.6	13	8.6
^{234}Th	2.0 nCi	4.1	2.1	5.4

Detection of uranium in the lungs is generally used only for relatively insoluble (class W or Y) forms. The ^{235}U and ^{234}Th measurements can be used as independent checks on potentially positive results. The ^{234}Th (assumed to be in secular equilibrium with ^{238}U) is slightly more sensitive in terms of total uranium than ^{235}U detection for most Hanford mixtures, and is the basis for the minimum detectable dose analyses.

TABLE IV.1 Minimum Detectable CEDEs for 5-μm AMAD Class W Acute Inhalation Intakes of Recycled Uranium [a] for Elemental Uranium in Urine or Chest Counting.

Day Post-Intake	Measurement Interval	CEDE (mrem)	
		Elemental U in Urine[b]	^{234}Th by Chest Count[c]
1	Special	0.031	200
2	Special	0.10	240
7	Special	0.24	310
14	Special	0.44	350
30	Monthly	1.1	430
90	Quarterly	5.1	900
180	Semiannual	18	2900
365	Annual	150	NA
730	Biennial	1200	NA

(a) Multiply doses by 0.68 for natural uranium and by 0.32 for depleted uranium.
(b) Based on screening level of 0.2 μg/d urine excretion, implying an occupationally attributed 0.18 μg/d above the environmental geometric mean level of 0.02 μg/d.
(c) Based on detection of 1.5 nCi of ^{234}Th by chest counting, implying the presence of 2.7 nCi recycled uranium in the lungs.

NA=Not Applicable

TABLE IV.2 Minimum Detectable CEDEs for 5-μm AMAD Class Y Acute Inhalation Intakes of Recycled Uranium Mixture,[a] Detected by Elemental Uranium in Urine or Chest Counting.

		CEDE (mrem)	
Day Post-Intake	Measurement Interval	Elemental U in Urine[b]	^{234}Th by Chest Count[c]
1	Special	4.6	2400
2	Special	15	2900
7	Special	39	3500
14	Special	67	3600
30	Monthly	190	3600
90	Quarterly	790	3900
180	Semiannual	1100	4200
365	Annual	1100	5100
730	Biennial	1200	7100

(a) Multiply doses by 0.76 for natural uranium and 0.39 for depleted uranium.
(b) Based on screening level of 0.2 μg/d urine excretion, implying an occupationally attributed 0.18 μg/d above the environmental geometric mean level of 0.02 μg/d.
(c) Based on detection of 1.5 nCi of ^{234}Th by chest counting, implying the presence of 2.7 nCi recycled uranium mixture in the lungs.

TABLE IV.3 Minimum Detectable CEDEs for 5-μm AMAD Class D Acute Inhalation Intakes of Recycled Uranium [a] Based on Elemental Uranium Detected in Urine[b].

Day Post-Intake	Measurement Interval	Intake mg)	CEDE (mrem)
1	Special	.0021	0.007
2	Special	.0064	0.021
7	Special	.018	0.059
14	Special	.033	0.11
30	Monthly[c]	.095	0.31
90	Quarterly	1.1	3.5
180	Semiannual	19	63
365	Annual	95	310
730	Biennial	110	350

(a) Multiply doses by 0.67 for natural uranium and 0.33 for depleted uranium.
(b) Based on screening level of 0.2 μg/d urine excretion, implying an occupationally attributed 0.18 μg/d above the environmental geometric mean level of 0.02 μg/d.
(c) Recommended frequency based on potential chemical toxicity of intakes.

EXHIBIT 5.5

BIOASSAY CAPABILITY FOR PLUTONIUM

In Vivo Lung Counting

MDA: 0.16 nCi for ^{241}Am for 3000-s count

Plutonium in the lungs can be monitored by measuring the ^{241}Am daughter of ^{241}Pu using planar germanium-detector chest-counting techniques. This method is state-of-the-art for in vivo detection in the lungs, but is limited in usefulness to aged plutonium mixtures, where sufficient time has elapsed to allow significant ^{241}Am ingrowth. Program capabilities for chest counting are shown in Tables V.1 and V.2. The capability in terms of minimum detectable dose assumes that material at the time of intake is either 6% ^{240}Pu or 12% ^{240}Pu mixture, aged 20 years to allow ^{241}Am ingrowth as discussed in the *Methods and Models of the Hanford Internal Dosimetry Program (PNNL-MA-860)*. Urine sampling is generally more effective than chest counting for routine monitoring of class W forms of plutonium. Chest counting is primarily of value immediately following intakes, or as a monitoring technique for class Y (or less soluble) forms of plutonium.

Urine Bioassay Analyses

Plutonium in Urine (IPU)

MDA = 0.02 dpm/sample $^{239+240}$Pu
(assumed 0.02 dpm/d)

Isotopic plutonium is normally analyzed in a simulated 24-hr urine sample. The MDA is assumed to apply to a daily excretion rate. The minimum detectable doses for fresh and aged plutonium mixtures are shown in Table V.3.

TABLE V.1 Minimum Detectable CEDEs for Acute 5-μm AMAD Inhalation Intakes of Class Y Plutonium Mixtures Based on MDA Chest Count of ^{241}Am (0.16 nCi) at Indicated Day Post-Intake.

Day Post-Intake	Measurement Interval	CEDE (rem) 20-Y Aged Weapons-Grade Pu	CEDE (rem) 20-Y Aged Fuel-Grade Pu
1	Special	1.8	0.78
2	Special	2.0	0.96
7	Special	2.4	1.1
14	Special	2.5	1.1
30	Monthly	2.5	1.2
60	Bimonthly	2.6	1.2
90	Quarterly	2.6	1.3
180	Semiannual	2.9	1.4
365	Annual[(a)]	3.4	1.6
730	Biennial	4.8	2.2

(a) Recommended frequency.

TABLE V.2 Minimum Detectable CEDEs for Acute 5-μm AMAD Inhalation Intakes of Class W Plutonium Mixtures Based on MDA Chest Count of ^{241}Am (0.16 nCi) at the Indicated Day Post Intake.

Day Post-Intake	Measurement Interval	CEDE (rem) 20-Y Aged Weapons-Grade Pu	CEDE (rem) 20-Y Aged Fuel-Grade Pu
1	Special	5.9	3.0
2	Special	7.0	3.5
7	Special	8.8	4.6
14	Special	9.6	4.9
30	Monthly	12	6.3
60	Bimonthly	18	8.8
90	Quarterly	26	13
180	Semiannual	80	42
365	Annual	880	440
730	Biennial	1.0E+5	5.5E+4

TABLE V.3 Minimum Detectable CEDEs for 5-μm AMAD Aged Weapons-Grade Pu Mixtures[a] Based on MDA Detection (0.02 dpm/d) of ^{239}Pu in Urine by Isotopic Plutonium Analysis (IPU).

Day Post-Intake	Measurement Interval	CEDE (rem) Class W Inhalation	CEDE (rem) Class Y Inhalation
1	Special	0.017	0.068
2	Special	0.026	0.11
7	Special	0.13	0.55
14	Special	0.21	0.89
30	Monthly	0.29	1.2
60	Bimonthly	0.41	1.8
90	Quarterly	0.53	2.1
180	Semiannual	0.72	2.6
365	Annual[b]	1.2	3.3
730	Biennial	2.2	3.8

(a) For 5-μm AMAD, 20-y aged Fuel Grade Pu mixture, multiply Weapons-Grade values by 1.6 to give an approximate minimum detectable CEDE. Contact the IDP staff for unusual mixtures.

(b) Recommended frequency.

EXHIBIT 5.6

BIOASSAY CAPABILITY FOR STRONTIUM-CESIUM MIXTURES

Bioassay for mixtures of ^{90}Sr and ^{137}Cs may include whole body counting for ^{137}Cs, urinalysis for ^{90}Sr, or a combination of both. The minimum detectable doses (CEDE) shown below assume acute intakes of 5-μm AMAD class D forms of these materials.

Days Post Intake	Bioassay Type	1:1	10:1	20:1	40:1	100:1	1000:1
1	WBC[(a)]	0.60	5.2	10	21	52	520
	Urine[(b)]	0.03	0.02	0.02	0.02	0.02	0.02
2	WBC[(a)]	0.63	5.5	10	21	54	540
	Urine[(b)]	0.03	0.03	0.03	0.03	0.03	0.03
7	WBC[(a)]	0.68	5.9	12	24	59	580
	Urine[(b)]	0.08	0.07	0.07	0.07	0.07	0.07
14	WBC[(a)]	0.72	6.3	12	25	61	610
	Urine[(b)]	0.25	0.22	0.22	0.21	0.21	0.21
30	WBC[(a)]	0.78	6.8	13	27	68	680
	Urine[(b)]	2.2	1.9	1.9	1.9	1.8	1.8
90	WBC[(a)]	1.2	10	20	41	99	990
	Urine[(b)]	9.5	8.2	8.2	8.1	8.1	8.1
180	WBC[(a)]	2.1	18	35	71	180	1800
	Urine[(b)]	15	13	13	13	13	13
365	WBC[(a)]	6.7	59	120	240	580	5800
	Urine[(b)]	30	26	26	26	26	26
730	WBC[(a)]	68	590	1200	2400	5900	58000
	Urine[(b)]	71	62	61	61	61	61

(a) Based on 1.7 nCi ^{137}Cs MDA and are similar for both NaI preview counter and coaxial Ge system.

(b) Based on 10 dpm MDA for ^{90}Sr urinalysis.

EXHIBIT 5.7

BIOASSAY CAPABILITY FOR CESIUM-PLUTONIUM MIXTURES AND STRONTIUM-PLUTONIUM MIXTURES

Waste mixtures such as are found in tank farm facilities or storage basins often contain relatively large quantities of fission product activity (^{137}Cs and/or ^{90}Sr) and trace quantities of plutonium. Because periodic bioassay for plutonium is relatively insensitive, cost-effective bioassay programs can sometimes make us of ^{137}Cs and/or ^{90}Sr as an indicator radionuclide for the possible presence of plutonium. The indicator bioassay concept involves a screening measurement for the indicator nuclide. If the indicator nuclide is present, inference is made that plutonium may also be present, initiating an investigation which may include special follow-up bioassay measurements. The capability and adequacy of indictor bioassay programs for the mixture depends on the activity ratio of the indicator relative to plutonium.

Tabulations are provided in this exhibit for ^{137}Cs + ^{239}Pu mixtures and ^{90}Sr + ^{239}Pu mixtures. Various activity ratios for the mixtures at intake are addressed. In both sets of tabulations, the indicator nuclide (^{137}Cs or ^{90}Sr) is assumed to be inhalation class D form and ^{239}Pu is assumed to be class W. These assumptions are considered reasonable because the mixtures involved typically are of an aqueous or semi-aqueous nature (waste tank contents, storage basin sludges, etc). The minimum detectable doses for class Y plutonium would be substantially lower than those tabulated for class W. It was also assumed that all intakes were by inhalation of 5-μm AMAD aerosols. The activity ratios of the indicator relative to ^{239}Pu are suitable for gross alpha activity smear or air sample results and can also be extended to pure isotopes (including ^{241}Am) for the purposes of bioassay program design. Minimum detectable doses would vary slightly between plutonium isotopes but would generally be less than a 10 percent variation.

Bioassay for mixtures of ^{137}Cs and alpha-emitting isotopes of Pu can be accomplished by using whole body counting as a screening tool for many mixtures, if there is reasonable assurance about the likely or worst-case activity ratios. If nothing is detected by the screening whole body count, no additional bioassay need be performed. If ^{137}Cs is detected, then at least one supplemental urinalysis should be performed to provide monitoring capability approximately comparable to those workers on periodic plutonium bioassays. More in-depth evaluation may include plutonium fecal samples, as might be performed for suspected plutonium intakes.

In a similar approach, screening bioassay for mixtures of ^{90}Sr and plutonium can be accomplished by a ^{90}Sr urinalysis. This screening technique may be particularly suitable for waste tank sludges that tend to be rich in ^{90}Sr and plutonium but somewhat reduced in ^{137}Cs.

^{137}Cs and Pu Mixtures

Days Post Intake	Minimum detectable dose (CEDE) for ^{137}Cs: ^{239}Pu ratios at intake (mrem)[a]				
	1:1	10:1	40:1	100:1	1,000:1
1	920	92	24	9.3	1.0
2	950	95	24	9.6	1.1
7	1,000	100	26	11	1.1
14	1,100	110	27	11	1.2
30	1,200	120	30	12	1.3
90	1,800	180	44	18	2.0
180	3,100	310	78	31	3.4
365	10,000	1,000	260	100	11
730	100,000	10,000	2,600	1,000	11

(a) Based on 1.7nCi ^{137}Cs MDA for whole body counter, assuming 5-μm AMAD aerosol, class D Cs and class W Pu. Similar for NaI and coaxial Ge detector systems.

^{90}Sr and Pu Mixtures

Days Post Intake	Minimum detectable dose (CEDE) for ^{90}Sr: ^{239}Pu ratios at intake (mrem)[b]			
	1000:1	600:1	100:1	10:1
1	0.06	0.1	0.4	4.0
2	0.08	0.1	0.5	4.9
7	0.2	0.3	1.3	13
14	0.59	0.8	4.0	38
30	5.1	7.3	35	330
90	23	32	150	1,500
180	36	52	250	2,300
365	72	100	490	4,600
730	170	240	1,100	11,000

(b) Based on 10 dpm ^{90}Sr MDA for one-day urine sample, assuming 5-μm AMAD aerosol, class D Sr and class W Pu.

EXHIBIT 5.8

PRENATAL BIOASSAY PROGRAM

For most radionuclides the dose to embryo/fetus will be similar to or less than the dose to the corresponding maternal tissues, but current guidance requires the dose to the embryo/fetus to be calculated separately. Bioassay results from shortly after the date the pregnancy was declared and following the end of the pregnancy are adequate to demonstrate compliance with dose limits. The following table shows the maximum dose received by the embryo/fetus following an inhalation intake by the mother that results in an excretion or retention of radioactive material at the end of pregnancy equal to the minimum detectable activity for the bioassay analysis used.

Minimum Detectable Dose for Prenatal Bioassay Program

Inhalation				Minimum Detectable Dose[a], mrem	
Nuclide	Class	Analysis[b]	MDA	Acute Intake	Chronic Intake
^{238}Pu	W	Urine	0.02 dpm	0.1	1E-4
^{238}Pu	Y	Urine	0.02 dpm	0.7	3E-4
^{239}Pu	W	Urine	0.02 dpm	0.1	1E-4
^{239}Pu	Y	Urine	0.02 dpm	0.7	3E-4
U	D	Urine	0.2 µg	0.001	2E-7
U	Y	Urine	0.2 µg	0.2	4E-5
^{90}Sr	D	Urine	10 dpm	0.001	1E-6
^{90}Sr	Y	Urine	10 dpm	3.3	2E-3
^{137}Cs	D	In Vivo	1.7 nCi	0.6	2E-4

(a) Effective dose equivalent to the embryo/fetus for the 9-month gestation period.
(b) All urinalyses assumed to represent total 24-hour excretion.

EXHIBIT 5.9

GRACE PERIOD TECHNICAL JUSTIFICATION

The adoption of a grace period for routine bioassay measurements, consisting of the scheduled month and the next month following, implies that as much as two months may pass beyond the scheduled date of a measurement and the date that it is actually obtained. The impact of this potential delay on the minimum detectable dose (committed effective dose equivalent) as an indication of bioassay program sensitivity for various circumstances is discussed below. All inhalation intakes were based on 5-μm AMAD particle size.

Annual Bioassays

Class Y Pu Urinalysis:	No significant change in MDD from semi-annual to biennial (MDD goes from 2.6 rem semi-annual to 3.8 rem biennial). Thus, choice of grace period date for this case is independent of technical considerations about MDD.
Class W Pu Urinalysis:	Change from annual to biennial results in doubling of MDD (1.2 to 2.2 rem). A grace period of even a year would still provide an adequate safety net with regard to compliance with the dose limit.
Class Y U Urinalysis:	Change from semi-annual to biennial results in <10% change in MDD (1.1 rem to 1.2 rem for recycled uranium). Grace period choice is independent of technical MDD considerations.
Class W U Urinalysis:	Change from annual (150 mrem) to biennial (1,200 mrem) is a significant impact on the MDD, but still provides an adequate safety net with regard to the dose limit. A lengthy grace period (i.e., several months for an annual sample, can still be ok.)
Class D Sr Urinalysis:	Change from annual (26 mrem) to biennial (61 mrem) has no significant impact on MDD. Thus, choice of grace period date for this case is independent of technical considerations about MDD.
Acute Class Y Pu Chest Counts	Shifting from annual to biennial chest counts changes the MDD from 3.4 rem to 4.8 rem for 20-y aged weapons grade Pu and 1.6 rem to 2.2 rem for 20-y aged fuel grade Pu. A two month grace period date for this case has no significant technical impact on MDD.
Acute Class Y Recycled U Chest Counts	Shifting from annual chest counts (5.1 rem) to biennial (7.1 rem) has minor impact on MDD. A two month grace period date for this case has no significant technical impact on MDD.

10:1 Cs to Pu Mixtures	(For ratios <10:1, Pu bioassay is recommended)
Whole Body Count	Shifting from annual WBC (MDD of 1,000 mrem) to 14 months (MDD of 1,800 mrem) has modest impact but does not affect the ability to show compliance with the dose limit. A two-month grace period date for this case would seem acceptable from a technical standpoint.

Semi-Annual Bioassays

No present bioassay programs are recommended with semi-annual urinalyses.

Quarterly Bioassays

Infrequent / acute Class W U Urinalysis:	Quarterly (5.1 mrem) to semi-annual (18 mrem) has no significant impact on MDD. Thus, choice of grace period date for this case is independent of technical considerations about MDD.
Chronic / multiple acute Class Y U Urinalysis:	Quarterly (790 mrem) to semi-annual (1,100 mrem) has modest impact on MDD but does not affect the ability to show compliance with the dose limit. Thus, choice of grace period date for this case is independent of technical considerations about MDD.

Monthly Bioassays

Tritium	Shift from biweekly (0.07 mrem) to bimonthly (1.6 mrem) has no significant impact on MDD. Thus, choice of grace period date for this case is independent of technical considerations about MDD. If a bi-weekly or monthly sample is missed, there is no problem with waiting until the next one comes up. Missing two in a row is reasonable grounds for work restriction.
Soluble U Urinalysis:	None of these are currently being performed, and chemical toxicity, not internal dose, is not the driving technical factor for the measurements. Changing from monthly (12 ug/d screening level for chemical toxicity) to a quarterly sample (1.1 ug/d for chemical toxicity) is not likely to have a major impact.
Post Job	The selection of a sampling time following completion of a job is not a significant technical issue for Pu, U, ^{90}Sr, or even ^{3}H. Because routine monitoring programs are typically at much longer frequencies, a suggested sample late date is one-month following completion of the work.

EXHIBIT 5.10

DETERMINING THE POTENTIAL INTAKE FRACTION

The Potential Intake Fraction (*PIF*) is a tool developed for determining the levels of activity above which routine bioassay is recommended. It can be thought of as the fraction of material in process which might reasonably be considered to be available for intake by those directly involved with the process. The default *PIFs* shown in Table 5.3 were adopted at Hanford in 1989 with the first issue of PNL-MA-552. The values were based on concepts and related methods under development or established by the USNRC, as well as DOE work. Consensus standard work in the late 1990s resulted in a refined version of this method being included as Appendix A to ANSI/HPS N13.39-2001, Design of Internal Dosimetry Programs – Minimum Requirements. Appendix A to that standard contains a refined version of the material in process method. Of particular interest in the refinement is the method by which the PIF is determined. N13.39 provides factors for release, confinement, dispersibility, and occupancy. In so doing, the N13.39 *PIF* is a substantially more robust tool allowing for more complex conditions. In particular, N13.39 addresses the frequency at which work is performed, whereas the original PNL-MA-552 did not. The N13.39 method described below may be used to calculate *PIFs* in lieu of the conservative default values of Table 5.3.

$$PIF = 10^{-6} \times R \times C \times D \times O \times S$$

Where R = release factor (dimensionless)
C = confinement factor (dimensionless)
D = dispersibility factor (dimensionless)
O = occupancy factor (dimensionless)
S = special form factor (dimensionless)

Release Factors, *R*:	
1.0	Gases, strongly volatile liquids
0.1	Nonvolatile powders, somewhat volatile liquids
0.01	Liquids
0.01	General (large area) contamination
0.001	Solids, spotty contamination, material trapped on large particles (i.e., resins)
0	Encapsulated material

Confinement Factors, *C*	
0.01	Glovebox, hot cell
0.1	Enhanced fume hood (enclosed hood with open ports for arms)
1.0	Fume hood, bagged material in DOT drums or steel boxes
10	Bagged or wrapped contaminated materials, bagged material in wooden or cardboard boxes, greenhouses
100	Open bench-top or surface contamination in a room with normal ventilation

Dispersibility Factor, *D*	
10	Situations where energy is added to the material in a manner that increases dispersibility (e.g., heating, cutting, grinding, milling, welding, pressurizing, or exothermic chemical reactions).
1	All others

EXHIBIT 5.10 DETERMINING THE POTENTIAL INTAKE FRACTION (Cont.)

Occupancy Factor (frequency of work), *O*	
1	Annually, or essentially one time
10	Monthly, or a few times a year
50	Weekly, 10s of times a year, or 10s of days for a one-time project
250	Essentially daily contact

Special Form Factor, *S*	
1	Normal value. Allowance may be made for chemical or physical forms not normally taken into account when using standard ALIs, for instance radioactive tracers tagged to special chemical compounds. At this time there are no standard adjustments to this value.

The *PIFs* determined by the two methods for the circumstances currently tabulated in PNL-MA-552 are shown below, along with the factor by which the current determination of material in process would be multiplied for a one-time task and daily (250 day/year) work under the given circumstances. If the N-13.39 PIF values are used, then the current values of Table 5.2 could be modified by the factors shown in the far right column below to represent one-time processes and continuing (daily) processes.

Circumstance	PIF by PNL-MA-552 Table 5.3	PIF by HPS N13.39 One-Time (Daily)	Impact of N13-39 method on material in process for bioassay as ratio of revised to current value in Table 5.2 One-Time and (Daily)
Powder in glovebox	1E-5	1E-9 (2.5E-7)	10,000 (40)
Powder in open hood	1E-4	1E-7 (2.5E-5)	1000 (4)
Powder in open area	1E-3	1E-5 (2.5E-3)	100 (0.4)
Liquids in glovebox	1E-7	1E-10 (2.5E-8)	1000 (4)
Liquids in open hood	1E-6	1E-8 (2.5E-6)	100 (2.5)
Liquids in open area	1E-5	1E-6 (2.5E-4)	10 (0.04)
Grinding in glovebox	1E-8	1E-10 (2.5E-8)	100 (2.5)
Grinding in open hood	1E-7	1E-8 (2.5E-6)	10 (0.04)
Grinding in open area	1E-6	1E-6 (2.5E-4)	1 (0.004)

HANFORD INTERNAL DOSIMETRY PROGRAM MANUAL
PNL-MA-552

SECTION 6.0, BIOASSAY SERVICES

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Reviewer Signatures:

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C.L. Antonio, Dosimetrist

Approved by the Hanford Personnel Dosimetry Advisory Committee as recorded in the meeting minutes of January 10, 2007.

6.0 Bioassay Services

After a bioassay monitoring need has been identified and the appropriate types of measurements have been determined, the measurements need to be scheduled and performed. This chapter describes the normal bioassay services provided through the IDP, the scheduling of bioassay samples, and the generation, reporting, and follow-up of data. Special services not included here may be obtainable by contacting Internal Dosimetry.

Frequently used telephone numbers and mail stops for bioassay services are:

- Internal Dosimetry Office, 376-7245, B1-60
- IVRRF, 376-6102, B1-60
- Dosimetry Records, 376-7247, P7-01
- General Engineering Laboratories, Richland, 943-2121.

6.1 Indirect Bioassay Measurement Services

The indirect bioassay analyses are performed by the Analytical Services Laboratory (Lab). Terms applicable to Lab services are provided in the Glossary. The Lab is responsible for the following activities:

- Providing sample kits, including kit delivery and pickup at designated locations (usually worker residences) within a 75-mile radius of Richland. (Field Dosimetry is responsible for kit delivery and pickup outside this range unless a mailer kit is used.) Delivery and pickup of routine and priority samples are usually available on business days only.
- Attempting a second pickup of a "container not out" sample on a day specified by Field Dosimetry, within 10 days after the originally scheduled pickup.
- Analyzing urine and fecal samples in four processing categories: routine, priority, expedite, and emergency.
- Analyzing miscellaneous samples, such as air filters, smears, blood, tissue specimens, or cloth, by emergency or priority processing

Provisions have been made for obtaining bioassay samples from workers outside the 75-mile service area through the use of mail and private carrier. Internal Dosimetry should be contacted if this method of bioassay sampling is to be done.

Kit Codes

The sample type and collection method are identified by the sample kit code. Kit codes that are available are described in Appendix B, Table B.4. Instructions for kit use are provided in Appendix D.

Lab Capability

The analytical and reporting requirements for the four processing categories as of FY 2007 are detailed in Tables 6.1 through 6.6. Changes in these requirements may occur from year to year. Therefore, Internal Dosimetry should be contacted if the most current information is needed.

Note that the contract detection levels (CL) listed are extracted from the contract statement of work (SOW) for the Lab and are considered the upper limit for acceptable performance. The minimal detectable activities (MDA) calculated for comparison with the CLs are based on the equations developed in the Multi-Agency Radiological Laboratory analytical Protocols Manual (MARLAP 2004).

Minimum Sample Size

Minimum volumes for valid samples are specified in the Lab's statement of work. They generally depend on the same kit code and processing category. Unless otherwise noted, the numeric kit code represents both sample delivery and pick-up and the letter kit code designation represents sample pick-up only. Values are shown below:

Kit Code	Application	Routine Processing	Other Processing
1,P	Approximate 24 hr	500 mL	20 mL
2,Q	12-hr Termination	20 mL	20 mL
3,R	Total 24-hr	500 mL	20 mL
4,S	Single Void Urine	20 mL	20 mL
5,T	Feces	not applicable	20 g
6,U	Approximate 12-hr.	250 mL	20 mL
7,V	12-hr weekend	250 mL	20 mL
8,W	Single Void Fecal	20 g	not applicable
9,X	Mailer Kit	20 mL	20 mL
A,Y	Approximate 48-hr	1000 mL	not applicable
B,Not Applicable	12-hr Term Sample "Delivery Only"	20 mL	20 mL

Tritium is an exception to these values. The minimum volume for tritium analysis is 20 mL, regardless of kit code. For other analyses, samples with less than the listed volumes shall be reported as insufficient volume (IS) and shall not be processed unless specifically directed otherwise by Internal Dosimetry.

TABLE 6.1 - Analytical and Reporting Requirements for Routine Processing of Samples

Analysis (Code)	Constituents Reported	Contractual Detection Level (dpm/sample) Urine	Fecal	Determination Time (business days following sample receipt)	Reporting Time Oral[g]	Electronic[a]	Written[a]	Oral Reporting Level[d]: (dpm/sample) Urine	Fecal
Pu(∝) Isotopic (IPU)	Pu-238, Pu-239, 240	0.02	0.2	20	By close of business on day of determination	Within five business days of determination	Within 10 business days of determination	Eq. 1	Eq. 1
Pu(∝) Isotopic (IPUL)	Pu-238, Pu-239, 240	0.005		30				Eq. 1	
Am-241 (AM241)	Am-241	0.02	0.8	20				Eq. 1	Eq. 1
Am-243 (AM243)	Am-243	0.02	0.8	20				Eq. 1	Eq. 1
Cm(∝) Isotopic (ICM)	Cm-242, Cm-244(b)	0.02		20				Eq. 1	
U(∝) Isotopic (IU)	U-233, 234, U-235, U-238	0.02		20				(f)	
Th(∝) Isotopic (ITH)	Th-228, Th-229, Th-230, Th-232	0.1	1	20				Eq. 1	Eq. 1
Tritium (H3)	H-3	20 dpm/ml		5				10dpm/ml	
Sr-total (SR)	Sr (sum Sr-89 + Sr-90)	10		20				5	
Sr-90 (SR90)[c]	Sr-90	10		30				5	
Gamma Spectroscopy (ISPEC)	K-40, Cs-137 + Others(d)	See Table 6-5		20				Eq. 1	
Gamma Spectroscopy (LEPD)	Am-241	5		20				Eq. 1	
U-nat (U)	Elemental U	0.06 µg/sample	0.3 µg/sample	20				0.2 µg/sample	0.2 µg/sample
Sequential Analyses:									
Pu(∝) Iso and Sr-total (IPS)	As for individual analyses	As for individual analyses		25	As for individual analyses				
Pu(∝) Iso, Am-241 (IPA)				25					
Pu(∝) Iso, Am-241, Sr-total (IPSA)				25					
Pu(∝) Iso, U-nat (IUPU)				25					
Actinide(∝) Isotopic (ITPAC)[e]				25					
Pu(∝) Iso and U ISO (IPIU)				25					

(a) Time allowed following determination of results to receipt of results by Internal Dosimetry.

(b) Report measured activity for Cm-246, and Cm-248 upon request of the Internal Dosimetry.

(c) If total strontium is less than 15 dpm, yttrium ingrowth is not required.

instruction, regardless of the activity measured.

(e) Pu (∝) Isotopic, Am-241, and Cm (∝) Isotopic.

(f) 0.16 dpm for U-234, 0.15 dpm for U-238, and the greater of 0.007dpm and Equation 1 for U-235.

(g) Oral report required only when analytical results exceed level specified.

Eq. 1 L_c=2x(combined standard uncertainty)

TABLE 6.2 - Analytical and Reporting Requirements for Priority Processing of Samples

Analysis (Code)	Constituents Reported	Contractual Detections Level(a) (dpm/sample) Urine	Feces	Determination Time (business days following sample receipt)	Reporting Time Oral(b)	Electronic(b)	Written(b)
Pu(∝) Isotopic (IPU)	Pu-238, Pu-239, 240	0.02	0.2	8	By close of business on day of determination	Within five business days	Within 10 business days
Cm(∝) Isotopic (ICM)	Cm-242, Cm-244,(c)	0.02	0.8	8			
U(∝) Isotopic (IU)	U-233, 234, U-235, U-238	0.02	0.3	8			
Ra(∝) Isotopic (IRA)	Ra-224, Ra-226	0.3	1.5	8			
Np-237 (NP237)	Np-237	0.02	0.1	8			
Am-241 (AM241)	Am-241	0.02	0.8	8			
Am-243 (AM243)	Am-243	0.02	0.8	8			
Th(∝) Isotopic (ITH)	Th-228, Th-229, Th-230, Th-232	0.1	1	8			
U-nat (U)	Elemental U	0.06 µg/sample	0.3 µg/sample	8			
Tritium (H3)	H-3	20 dpm/ml		3			
C-14 (C14)	C-14	10 dpm/ml	200	3			
Sr-total (SR)	Sr (sum Sr-89 + Sr-90)	10	30	7			
Sr-Isotopic (ISR)	Sr-89, Sr-90	30, 30 respectively	45, 30 respectively	15(e)			
Sr-90 (SR90)	Sr-90	10	30	15(e)			
Pu-241 (PU241)	Pu-241	10	10	9			
Gamma Spectroscopy (ISPEC)	K-40, Cs-137 + Others(d)	See Table 6-5	See Table 6-5	3			
Gamma Spectroscopy (LEPD)	Am-241	5	5	8			
Sequential Analyses:							
Pu(∝) Iso and Sr-total (IPS)	As for individual analyses	As for individual analyses		9			
Pu(∝) Iso, Am-241 (IPA)				9			
Pu(∝) Iso, Am-241, Sr-total(IPSA)				9			
Pu(∝) Iso, Pu-241 (IPUB)				9(f)			
Pu(∝) Iso, Pu-241, Am-241 (IPUBA)				9(f)			
Pu(∝) Iso, U-nat (IUPU)				9(g)			
Pu(∝) Iso and UISO (IPIU)				9			

(a) CL is stated in terms of dpm/sample for fecal samples of 20 to 500 g.

(b) Time allowed following determination of results to receipt of results by Internal Dosimetry.

(c) Report measured activity for Cm-246, and Cm-248 upon request of the Internal Dosimetry.

(d) Report all isotopes present at levels exceeding one-half the appropriate CL listed in Table 6-5. If ordered by the Internal Dosimetry, report results for radionuclides in Table 6-5 specified in the processing instructions, regardless of the activity measured.

(e) Sr-90 to be determined within 15 business days. Total Strontium to be determined within 7 business days and reported orally upon determination. If total strontium is less than 15 dpm, yttrium in-growth is not required.

(f) Pu-241 to be determined within 16 business days.

(g) U-nat to be determined within 12 business days.

TABLE 6.3 - Analytical and Reporting Requirements for Expedite Processing of Samples

Analysis (Code)	Constituents Reported	Contractual Detections Level(a) (dpm/sample) Urine	Feces	Reporting Time Oral (e)	Electronic(b)	Written(b)
Pu(∝) Isotopic (IPU)	Pu-238, Pu-239, 240	0.08	3	By 9:00 a.m. on 2nd business day following sample receipt	Within five business days	Within 10 business days
Cm(∝) Isotopic (ICM)	Cm-242, Cm-244(c)	1.2	70			
U(∝) Isotopic (IU)	U-233, 234, U-235, U-238	0.12	4			
Ra(∝) Isotopic (IRA)	Ra-224, Ra-226	0.3	3			
Am-241 (AM241)	Am-241	0.08	6			
Am-241 (AM241)	Am-241	0.08	6			
Np-237 (NP237)	Np-237	0.12	3			
Th (∝) Isotopic (ITH)	Th-228, Th-229, Th-230, Th-232	0.1	1			
U-nat (U)	Elemental U	0.5 µg/sample	5 µg/sample			
Tritium (H3)	H-3	100 dpm/ml				
C-14 (C14)	C-14	20 dpm/ml	2000			
Pm-147 (PM147)	Pm-147	50	2000			
Sr-total (SR)	Sr (sum Sr-89 + Sr-90)	50	150			
Gamma Spectroscopy (ISPEC)	K-40, Cs-137 + Others(d)	See Table 6-5	See Table 6-5			
Gamma Spectroscopy (LEPD)	Am-241	5	5			
Sequential Analyses: Pu(∝) Iso, Am-241 (IPA)	As for individual analyses	As for individual analyses		As for individual analyses		
Pu(∝) Iso, Sr-total (IPS)						
Pu(∝) Iso, Sr-total, Am-241 (IPSA)						
Pu(∝) Iso, U-nat (IUPU)						

(a) Detection level in terms of dpm/300 ml for urine samples in excess of 300 ml. CL is stated in terms of dpm/sample for fecal samples of 20 to 500 g.

(b) Time allowed following oral report to delivery of results to the Internal Dosimetry.

(c) Report measured activity for Cm-246, and Cm-248 upon request of the Internal Dosimetry.

(d) Report all isotopes present at levels exceeding one-half the appropriate CL listed in Table 6-5. If ordered by the Internal Dosimetry, report results for radionuclides in Table 6-5 specified in the processing instructions, regardless of the activity measured.

(e) Oral report required for all analytical results.

TABLE 6.4 - Analytical and Reporting Requirements for Emergency Processing of Samples

Analysis (Code)	Constituents Reported	Contractual Detections Level(a) (dpm/sample) Urine	Feces	Reporting Time Oral (b)	Electronic(e)	Written(c)
Pu(∝) Isotopic (IPU)	Pu-238, Pu-239, 240	0.5	9	24	Within five business days.	Within ten business days.
Cm(∝) Isotopic (ICM)	Cm-242, 244 + Others(d)	10	240	24		
U(∝) Isotopic (IU)	U-233, 234, U-235, U-238	1	12	24		
Ra(∝) Isotopic (IRA)	Ra-224, Ra-226	2	10	24		
Th(∝) Isotopic (ITH)	Th-228, Th-229, Th-230, Th-232	0.5	2	24		
Am-241 (AM241)	Am-241	1	20	24		
Am-241 (AM241)	Am-241	1	20	24		
Np-237 (NP237)	Np-237	1	10	24		
U-nat (U)	Elemental U	7 µg/sample	8 µg/sample	24		
Tritium (H3)	H-3	100 dpm/ml	-	24		
C-14 (C14)	C-14	100 dpm/ml	10,000	24		
Pm-147 (PM147)	Pm-147	80	8,000	24		
Sr-total (SR)	Sr (Sr-89 + Sr-90)	80	450	24		
Gamma Spectroscopy (ISPEC)	K-40, Cs-137, + Others(e)	See Table 6-6	See Table 6-6	24		
Gamma Spectroscopy (LEPD)	Am-241	20	20	24		
Sequential Analyses:						
Pu(∝) Iso, Am-241 (IPA)	As for individual analyses	As for individual analyses	As for individual analyses	24		
Pu(∝) Iso, Sr-total (IPS)				24		
Pu(∝) Iso, Sr-total, Am-241 (IPSA)				24		
Pu(∝) Iso, U-nat (IUPU)				24		

(a) Detection level in terms of dpm/300 ml for urine samples in excess of 300 ml. CL is stated in terms of dpm/sample for fecal samples of 20 to 500 g.
(b) Hours following sample receipt. Oral report required for all analytical results. These time requirements apply for up to 25 (20 for LEPD) samples submitted at any one time.

(c) Time allowed following oral report to delivery of results to the Internal Dosimetry.

(d) Report measured activity for Cm-246, and Cm-248 upon request of the Internal Dosimetry.

(e) Report all isotopes present at levels exceeding one-half the appropriate CL listed in Table 6-6. If ordered by the Internal Dosimetry, report results for radionuclides in Table 6-6 specified in the processing instructions, regardless of the activity measured.

Table 6.5 - Contractual Detection Levels for Routine, Priority, and Expedite Processing of Gamma Spectroscopy Analysis[a]

Isotope	CL, Urine (dpm/sample)[b]	CL, Feces (dpm/sample)
^{60}Co	15	15
^{59}Fe	15	15
^{54}Mn	10	10
^{106}Ru	60	75
^{141}Ce	15	20
^{144}Ce	40	50
^{134}Cs	10	10
^{137}Cs	15	15
^{95}Zr	15	20
^{140}Ba	35	35
^{131}I	10	20
^{24}Na	15	15
^{22}Na	15	15
^{65}Zn	20	20
^{239}Np	25	30
^{241}Am	70	65

(a) The lab shall resolve and quantify unknown mixtures of gamma-emitting radionuclides. The nuclides and CLs listed shall be interpreted as a minimum requirement; the lab shall detect and quantify all other gamma emitters present at a nominal detection level of 20 dpm for each unspecified nuclide with E_γ >100 keV as relative to the energy and photon abundance ^{137}Cs.

(b) CL is in units of dpm/L, for samples greater than or equal to 1 L.

Table 6.6 - Contractual Detection Levels for Emergency Processing of Gamma Spectroscopy Analyses[a]

Isotope	CL, Urine (dpm/sample)[b]	CL, Feces (dpm/sample)
^{60}Co	35	35
^{59}Fe	35	55
^{54}Mn	20	35
^{106}Ru	115	220
^{141}Ce	20	35
^{144}Ce	75	145
^{134}Cs	20	30
^{137}Cs	20	35
^{95}Zr	30	50
^{140}Ba	60	115
^{131}I	15	25
^{24}Na	25	25
^{22}Na	25	25
^{65}Zn	40	65
^{239}Np	40	70
^{241}Am	100	180

(a) The lab shall resolve and quantify unknown mixtures of gamma-emitting radionuclides. The nuclides and CLs listed shall be interpreted as minimum requirements; the lab shall detect and quantify all other gamma emitters detectable using the same conditions as for the CLs listed.

(b) CL is in units of dpm/L, for samples greater than or equal to 10 mL.

6.2 In Vivo Measurement Services

Routine in vivo measurements are performed at the 747-A Building (805 Goethals, Richland). In vivo measurement services are summarized below and details are provided in the *In-Vivo Monitoring Program Manual* (PNL-MA-574). The type of measurement performed depends on the radionuclide(s) being tested for and the expected location of the radionuclide(s) in the body.

6.2.1 Whole Body Counts

Most gamma-emitting radionuclides can be easily detected by a standard whole body count. This measurement is normally scheduled as a periodic routine measurement or when an employee is newly hired, terminated, or beginning or ending a special project. Whole body counts are scheduled by Field Dosimetry through the REX System. A limited number of walk-ins can also be accommodated.

Routine whole body measurements are performed using two systems, the NaI or the HPGe (Coax Counter). The contractor/DOE office has the option of requesting a screening count on the Preview Counter, using the NaI stand-up detector system, or a 10-min whole body count using the HPGe co-axial counting system. If the Preview Counter indicates the presence of an occupationally related radionuclide, or if there are interferences that limit the usefulness of NaI spectrometry, the Coax Counter is also used. The Coax Counter uses an array of coaxial germanium detectors to better resolve and quantify radionuclides, especially in the presence of interfering radionuclides, such as radon progeny. Routine 10-minute coax counts are performed on workers for whom more sensitive measurements are required because of radionuclide mixture or potential interferences on the NaI system. A 20-minute follow-up measurement is performed using the co-axial counting system. If a result from either a screening count or a 10-min coaxial count exceeded the decision.

A mobile whole body counter is available which has technology and sensitivities comparable to the Preview Counter. This system is contained in a trailer and requires substantial lead-time for assembly and relocation.

Table 6.7 lists the detection capabilities for radionuclides routinely quantified by the whole body exam. The Coax Counter provides sensitivity equal to or better than that of the Preview Counter for all listed radionuclides. A peak search analysis is performed on each spectrum to look for peaks from nuclides that are not normally expected to be present. The peak search is less sensitive than the library directed analysis.

Table 6.7 - Nominal Minimum Detectable Amount (MDA) Values for Whole Body Exams

Nuclide	Preview Counter MDA (nCi)[a]	Coax Counter MDA (nCi)[b]
^{40}K	10	7
^{60}Co	1.6	1.3
^{137}Cs	1.3	1.7
^{154}Eu	7.0	3.3

(a) The MDA values are for routine 200-s measurements with the Preview Counter (five cylindrical sodium-iodide detectors in a vertical array). The corresponding values for 200-s measurements with the mobile counter are comparable.

(b) The MDA values are for 600-s variable velocity scans with the coaxial germanium detector system positioned posteriorly to the supine subject. The corresponding values for 1200-s measurements will be decreased by a factor of approximately 1.4.

6.2.2 Chest Counts

Chest counting is performed when there is concern about the presence in the lung of radionuclides that emit photons with energies of less than 200 keV. A chest count must be scheduled in advance with the IVRRF staff. When possible, annual chest counts are scheduled to coincide with a worker's whole body measurement. The typical chest count lasts 50-min (code C). If a result from the initial chest count exceeds the decision level, a follow-up 60-min chest count (code C2) is performed. To improve sensitivity, in most cases, the spectrum from a 50-min and 60-min chest count is summed. Detection capabilities for chest counts are listed in Table 6.8. In addition chest counts may be scheduled to provide only americium-241 results (code CA), only uranium-235 and thorium-234 results (code CU), or the combination of all three results (code CC).

Table 6.8 - Nominal Minimum Detectable Activity (MDA) Values for Planar Germanium Detector In Vivo Measurements

Measurement and Radionuclide	MDA (nCi)
Normal Chest Count[a]	
^{241}Am	0.16
^{235}U	0.09
^{234}Th	1.50
Skeleton Burden by Head Count[b]	
^{241}Am	0.5
Liver Count[c]	
^{241}Am	0.17
Thyroid Count[d]	
^{125}I	0.80
^{131}I	0.10
Transuranic Wound Count (600-s count time)	
^{241}Am (59.5 keV x-ray)	Determined as needed
^{239}Pu (17.0 and 20.4 keV x-rays)	Determined as needed

(a) Values are for 3000-s measurements with four detectors for average size subject.
(b) Value is based on 3000-s measurement with two detectors positioned on the forehead.
(c) Value is based on 3000-s measurement with three detectors positioned over the liver for average size subject.
(d) Values are based on 600-s measurements with one 38 cm^2 detector positioned 10cm above the thyroid.

If activity is confirmed in a chest count, a measurement of chest wall thickness, a liver count, and a head count may also be needed to make appropriate corrections to the chest count data. These measurements may be performed on the same day or rescheduled for a later date. Ultrasound measurements are routinely scheduled on a two-year interval for workers with long-term detectable chest count activity.

6.2.3 Special Counts

Other counts performed by special request include liver counts (for low-energy photons), head counts (to determine skeletal content of low-energy photons), thyroid counts (for radioiodines), wound counts, and selected lymph node counts. These counts are normally performed as part of special investigations or as a long-term follow-up of known depositions. These counts are arranged through Internal Dosimetry.

Table 6.8 lists the detection capabilities for radionuclides emitting low-energy photons, which are analyzed using germanium detectors, assuming normal count times. Slightly lower MDAs can be achieved if longer count times can be arranged. The MDA values for wound counts or other tissues (e.g., lymph nodes) are highly

variable depending on the circumstances of the measurement. Contact Internal Dosimetry if additional information is required.

6.3 Scheduling and Recordkeeping

This section discusses scheduling of bioassay measurements, reporting of routine results to Field Dosimetry, and record keeping. Follow-up of detected activity is discussed in Section 6.4. Assessment of confirmed intakes is covered in Chapter 3.0, and response to incidents is described in Chapter 7.0.

6.3.1 Contacting the Worker

Contacts with the worker concerning the scheduling and results of bioassay measurements are usually conducted by Field Dosimetry. (During a response to an incident, both Field Dosimetry and Internal Dosimetry usually work directly with the worker.) Internal Dosimetry also consults with a worker at other times at the request of Field Dosimetry.

6.3.2 Scheduling Indirect Bioassay Measurements

Summary

Internal Dosimetry coordinates all bioassay measurement requests to the Lab, either through the IDP or the HRRP, using the REX database.

The details of scheduling depend on the reason the sample is needed. Currently used sample-reason codes are described in Table 6.9, and scheduling details categorized by reason type are discussed below.

Baseline, Termination, End of Assignment

To schedule a worker for a baseline, termination, or end-of-assignment sample, Field Dosimetry must

1. Complete a Dosimetry Change Request form (Exhibit 6.1 or a document containing similar information) and enter the information into the REX database. This deletes the old schedule (if there is one) and establishes the new schedule. The completed form is submitted to the HRRP for inclusion in the worker's radiation exposure file. (A Dosimetry Change Request form is not needed for beginning and end-of-assignment samples for planned offsite exposures.)

2. Internal Dosimetry staff are responsible for reviewing special requests and the transmittal to the Lab.

Table 6.9 - Bioassay Measurement Reason Codes for the REX System

Code	Name	Description
BL	Baseline	Measurement is performed to establish a reference level against which subsequent measurements will be compared. This may be for new or established employees prior to commencing work with radioactive materials, beginning a specific type of radiation zone work, or making an offsite trip where potential internal exposure could occur.
CR	Contractor Request	Measurement is requested by employer for reasons other than periodic, baseline, end-of-assignment, or special investigation.
EA	End of Assignment	Measurement is performed following completion of a specific work assignment, but not end of employment.
HL	Pick up and Hold	Collect sample but hold for analysis pending instruction from IDP.
PR	Periodic	Measurement is performed at a regularly scheduled interval.
QR	Quality and Research	Measurement is performed as part of quality control, quality assurance, or research work.
RA	Reanalysis A	First reanalysis of sample, by taking another aliquot and repeating the same radiochemical or chemical analysis.
RB	Reanalysis B	Second reanalysis of sample, by taking another aliquot and repeating the same radiochemical or chemical analysis.
R1	Recount 1	First recount of original excreta sample or repeat in vivo exam.
R2	Recount 2	Second recount of original excreta sample or repeat in vivo exam.
SP	Special	Measurement is performed as part of a specific investigation of potential internal dose. May include response to off-normal work conditions, or follow-up of abnormal periodic measurements.
TM	Termination	Final bioassay at termination of employment.
12	Contract Work	In vivo measurement performed under contract to customers rather than Hanford employees.
20	Source Count	In vivo source count is made for system calibration or as a function check, usually using a known check source.
30	Background Count	In vivo system background measurement is performed for system calibration or as a functional check.

Periodic

Field Dosimetry initiates the request for a periodic bioassay measurement schedule by completing the Dosimetry Change Request form (Exhibit 6.1), and entering the information into the REX database. The completed form is sent to the HRRP for verification and filing in the worker's radiation exposure file.

Approximately one month before the scheduled sample time, a list of scheduled periodic samples is sent to Field Dosimetry for review. The reviewed list is then electronically transmitted to the Lab one week before the scheduled sample month. This pattern is repeated until another Dosimetry Change Request form is received.

If the periodic sample is not collected, is of insufficient volume, or is a failed analysis, the Lab notifies Internal Dosimetry, who then notifies Field Dosimetry. Field Dosimetry reschedules the sample request through the REX System. Internal Dosimetry transmits the request electronically to the Lab.

Contractor Request

Contractor-requested measurements are made by Field Dosimetry or the Internal Dosimetrist. An Explanation for Supplemental "Contractor Request" Bioassay Form (Exhibit 6.2 or equivalent) should be completed to explain the reason for the measurement and sent to HRRP.

Special, Reanalysis, Recounts

Special measurement requests, reanalysis, and recount requests are made by an Internal Dosimetrist after consultation with Field Dosimetry. During incident response, the Internal Dosimetrist often gives sample kits directly to the worker. The "special" measurement code is used while data are being collected for an evaluation. After a final evaluation has been made, samples collected for long-term surveillance of the intake are usually scheduled as periodic samples.

6.3.3 Excreta Sample Status

Once an excreta sample request has been submitted to the lab, it is assigned a status code that describes where that sample is in the process. Sample status codes are shown in the Administrative Tables/Excreta/Status Codes screen (KU12) of REX.

6.3.4 Reporting Results from Indirect Measurements

Valid Results

A result from a routinely processed sample is verbally or electronically reported or faxed to Internal Dosimetry by the Lab if the result exceeds the reporting level. Analytical and contractual reporting requirements for indirect bioassay measurements are included in Tables 6.1 through 6.6. All bioassay sample results are transferred electronically from the Lab to the REX database, as specified contractually. Results below the reporting level for samples other than reason code Special are sent a REX-generated letter (Exhibit 6.3).

Invalid or No Results

There are a number of reasons that a sample may not be obtained or a result not be provided. When such circumstances occur, the Lab notifies Internal Dosimetry to take appropriate follow-up action. These circumstances and appropriate actions are as follows:

Failed Analyses (FA)

An FA code indicates that a valid sample was provided by the worker but a valid analytical result could not be obtained. The majority of FA are a result of insufficient tracer recovery. Acceptable recovery levels are detailed in the statement of work. However, if a FA is a result of a laboratory error, then the lab should notify Internal Dosimetry by phone or by email and submits a nonconforming data report to the contract administrator, with a copy to Internal Dosimetry. Examples of these problems include spillage, cross-contamination, analytical procedure errors, inadequate yield, or out-of-specification quality control samples. Generally, a worker whose result is a failed analysis should be rescheduled for another sample and analysis.

Insufficient Volume Sample (IS)

If a urine sample does not meet the minimum volume requirement specified for the sample type (see Section 6.1), the sample is not analyzed and the IS code is noted in the REX database. A worker who provides an insufficient volume sample should be contacted to ensure that the sample kit instructions will be followed, and then the sample and analysis should be rescheduled.

Container-Not-Out (CN) If the kit was not out at the time of the scheduled pickup, a CN interim status code is assigned. The Lab will advise Internal Dosimetry of the attempted pickup and will make one more attempt to retrieve the container when notified of a revised pickup date. Samples not retrieved or scheduled for later retrieval within 10 business days of the scheduled pickup are assigned a "lost container" designation and should be rescheduled.

Lost Container (LC) The LC code means that the Lab delivered a sample kit but was unsuccessful in retrieving it. The sample should be rescheduled.

Not Delivered (ND) The ND code indicates that a scheduled sample kit was not delivered by the Lab. The sample should be rescheduled.

Not Evaluated (NE) The NE code shows a sample was obtained but a decision was made not to analyze the sample usually because the sample was redundant to other measurements or determined to be unnecessary.

No Sample (NS) The NS code means that a sample kit was delivered to the designated residence; however, it was not used and remained outside at the residence on the scheduled pickup date. The Lab notifies Internal Dosimetry of no samples. Internal Dosimetry then contacts Field Dosimetry. The sample should be rescheduled.

Cancelled Sample (CS) The CS code means that a scheduled sample was subsequently cancelled.

6.3.5 Scheduling In Vivo Bioassay Measurements

Summary In vivo measurements with reason codes of baseline, end-of-assignment, termination, periodic, and contractor-request are scheduled by Field Dosimetry using REX. The IVRRF has allocated to each contractor specific blocks of time for counting workers, and Field Dosimetry schedules their workers into those blocks. Whole body counts are scheduled by the day; chest and other counts are scheduled by the day and hour. Counts with the reason code "Special" may be scheduled directly with IVRRF, if necessary, although it is preferred to use REX if possible. Special counts may take precedence over other scheduled measurements.

Typical Measurements Field Dosimetry initiates the request for periodic in vivo measurements by completing the Dosimetry Change Request form (Exhibit 6.1 or a document containing similar information) and entering the information into the REX database.

The REX in vivo scheduling program identifies workers who are specified for a periodic in vivo exam in the coming month. Field Dosimetry then schedules whole body exams for individual workers using the contractor allocations of count times provided by the IVRRF. Each night REX sends an electronic file to the IVRRF containing the names of workers scheduled for exams the next day.

Unscheduled workers will also be accepted, although some rescheduling might be required.

Contractor Request Contractor-requested measurements are made by Field Dosimetry or the Internal Dosimetrist. An Explanation for Supplemental "Contractor Request" Bioassay Form (Exhibit 6.2 or equivalent) should be completed to explain the reason for the measurement and sent to HRRP.

Recounts Recounts are measurements performed on the same day as a positive count to confirm the initial measurement. Measurements performed at a later date as follow-up or because a same-day recount could not be performed are assigned the "special" code.

Special Special in vivo measurements are performed in response to an identified potential intake or as follow-up to a periodic measurement that exceeds a screening level. These measurements may be requested by the Internal Dosimetrist or the event contractor/DOE office. Timely completion of special measurements is a high priority and may preempt a scheduled measurement for a worker.

6.3.6 Reporting Results of In Vivo Measurements

Valid Results Internal Dosimetry is verbally notified if a measurement result exceeds the reporting level and is provided a copy of the measurement results. The reporting levels for routinely scheduled in vivo measurements are shown in Appendix A. In addition, results from special measurements are provided to Internal Dosimetry, along with a verbal notification, regardless of the level of the results. Internal Dosimetry, in turn, relays the results to Field Dosimetry with recommendations for follow-up, if necessary. Results are electronically transmitted to the REX database, usually within one week of the measurements.

No Results Invalid results or no results may be obtained for an in vivo measurement for a variety of reasons, such as a preliminary count that was followed by a record count on the same day, radon daughter interference, equipment problems, or interference from medically administered radioactivity. A comprehensive list of no-result codes is provided in Appendix B, Table B.14.

6.3.7 Reporting "No Shows"

Whether or not a worker reported for an in vivo measurement can be determined from the REX System. Following each day's measurements, IVRRF staff send an electronic "show" file to REX, listing workers who reported to IVRRF for exams, including unscheduled walk-ins. Walk-ins are scheduled at the time they show up at IVRRF. The actual measurement results are not part of this file.

REX generates a report by retrieving the "show" file and matching it with the day's schedule file. Matches and walk-ins appear as "shows." Workers scheduled but not listed in the "show" file are identified as "no-shows."

6.4 Follow-Up Measurements and Reports

Follow-up measurements and their associated documentation are handled as described in the following subsections.

6.4.1 Indirect Bioassay Measurements

The need for follow-up indirect bioassay measurements depends on the initial measurement result and its relationship to the screening levels of Appendix A.

≤ Screening Level

If the indirect bioassay measurement result is at or below the screening levels of Appendix A, no follow-up is performed by Internal Dosimetry and a computer-generated letter similar to Exhibit 6.3, is completed and sent to Field Dosimetry to be forwarded to the worker or the worker's manager.

> Screening Level

If the result is above the screening levels of Appendix A, different actions are taken, depending on the reason for the sample, according to the practices discussed in Chapter 2.0. If the reason code is for a baseline or special measurement, any result above the reporting level is investigated. If the reason code is for a periodic, contractor-request, end-of-assignment, or termination measurement, the result is compared with 1) the expected result because of any prior assessed intakes, and 2) a level that would possibly indicate an intake resulting in a CEDE greater than 10 mrem (see Appendix A). If the result is greater than expected or implies that an intake greater than the 10-mrem dose criterion has occurred, the result is investigated. Otherwise, a letter similar to Exhibit 6.3 is completed and sent to the worker and a copy to the HRRP for inclusion in the worker's radiation exposure file. A notification is also provided to Field Dosimetry. For Fluor Hanford, CH2M Hill Hanford Group, and DOE workers, the letter is sent directly to the worker and a notification is sent to Field Dosimetry. No follow-up is performed by Internal Dosimetry.

Recounts

If a routine- or priority-processed urinalysis for alpha-emitting nuclides exceeds the screening level but not the contractual detection level, Internal Dosimetry commonly requests two recounts. This step reduces random false-positive results that ensue from counting statistics alone. If both recounts are less than the screening level, a letter similar to Exhibit 6.3 is sent to the worker and a copy to the HRRP for inclusion in the worker's radiation exposure file. A notification is also provided to Field Dosimetry. For Fluor Hanford, CH2M Hill Hanford Group, and DOE workers, the letter is sent directly to the worker and a notification is sent to Field Dosimetry. If at least one recount is at or above the screening level, then Internal Dosimetry notifies Field Dosimetry and initiates a formal assessment of possible internal dose. Details about the assessment of internal dose are discussed in Chapter 3.0.

Recounts may be ordered under other circumstances at the discretion of the Internal Dosimetrist. Such recounts are appropriate to verify an unexpectedly high measurement.

Reanalysis

If a result exceeds the screening level for an analysis that required only an aliquot of the original sample, Internal Dosimetry may request reanalysis of that sample, provided that sufficient sample remains. If two reanalyses are below the screening level, the initial result is considered unconfirmed. If one reanalysis is also at or above the screening level, Internal Dosimetry notifies Field Dosimetry and initiates a formal assessment of possible internal dose. Details about the assessment of internal dose are discussed in Chapter 3.0.

6.4.2 In Vivo Measurements

The need for follow-up in vivo measurements depends on the measurement result and its relation to the screening levels listed in Appendix A. For in vivo measurements, the reporting levels are equal to the decision levels for the nuclides measured, except for naturally occurring ^{40}K, ^{208}Tl, and ^{214}Bi. IVRRF staff attempt to recount all unexpected positive results on the same day, if possible. If a recount or summed counts result exceeds the screening level, IVRRF staff report results of both initial and recount measurements to Internal Dosimetry. Internal Dosimetry then reviews the reported results against the applicable screening levels (see Appendix A) before determining the final disposition.

Preliminary Report

The worker receives a preliminary report on the results of in vivo measurements at the end of each visit to the IVRRF (see Exhibit 6.4). The preliminary report places the results of the measurements into one of four categories, and one of the four alternatives is selected in the body of the letter as appropriate:

- less than the decision level (results do not exceed criteria for follow-up)
- false-positive initial indication (for chest counts only)
- not immediately available (e.g., final calculations by computer are delayed or calculation/evaluation by hand is required)
- exceeded the decision level.

Final Report ≤ Screening Level

Where several screening levels may exist, depending on whether the measurement is a baseline or routine periodic assay, Internal Dosimetry determines the applicable screening level for each case. When a result is finalized, and if the result is at or below the screening level and is not associated with an incident, no follow-up is performed by Internal Dosimetry. If the information in the preliminary report needs no change, no further correspondence is necessary. If the final result differs from the preliminary report but no evaluation is necessary, the letter shown in Exhibit 6.5 is completed and sent to the worker. A copy of the letter is placed in the worker's radiation exposure file and a notification is provided to Field Dosimetry.

Final Report ≥ Screening Level

If the result is above the screening level, different actions are taken depending on the reason for the measurement, according to the practices discussed in Chapter 2.0. If the reason code is for a baseline, any result above the reporting level is investigated. If the reason code is for a periodic, contractor-request, end-of-assignment, or termination measurement, the result is compared with 1) the expected result because of prior assessed intakes, and 2) a level that might indicate an intake resulting in a CEDE greater than 10 mrem (see Appendix A). If the result is greater than expected or implies that an intake greater than the 10-mrem dose criterion has occurred, the result is investigated. Otherwise, the letter shown in Exhibit 6.5, with the appropriate box checked, is sent to the worker. A copy is placed in the worker's radiation exposure file, and Field Dosimetry is notified. No follow-up is performed by Internal Dosimetry.

6.5 Radiation Exposure (REX) Database

The results of all bioassay measurements are permanently retained in the REX database. The staff of Field Dosimetry, Internal Dosimetry, the IVRRF, and the Lab have access to only those parts of the REX database that are essential to their task responsibilities.

6.6 References

Health Physics Society (HPS). 1996. *Performance Criteria for Radiobioassay.* HPS N13.30-1996, McLean, Virginia.

MARLAP 2004. *Multi-Agency Radiological Laboratory Analytical Protocols Manual* (MARLAP). U.S. Environmental Protection Agency.

Pacific Northwest National Laboratory (PNNL). *In Vivo Monitoring Program Manual,* PNL-MA-574. Richland, Washington. (Internal manual.)

Exhibit 6.1 - Dosimetry Change Request

DOSIMETRY CHANGE REQUEST | Date:

Mail to:
Dosimetry
P7-04

FAX 373-2041

Manager's Name: _____ (Print) Phone: _____
Manager's Signature: _____
Fac./Area RadCon Name: _____ (Print)
Fac./Area RadCon Signature: _____

INCLUDE ANY/ALL CHANGES THAT APPLY

Company:

Name: | Payroll No./HID:

Job Title: | Dept. ID:

Building: | Area: | MSIN:

PLEASE REVIEW THE FOLLOWING TO ASSURE THAT ALL OF THE APPROPRIATE DOSIMETRY IS BEING REQUESTED FOR THE EMPLOYEE.

Change Dosimeter Exchange Frequency to:

Effective Date: _____
Dosimetry Use Only

Hanford Standard Dosimeter
- ☐ Annual
- ☐ Quarterly
- ☐ Monthly

Combination Neutron
- ☐ Annual
- ☐ Quarterly
- ☐ Monthly

PNAD
- ☐ Assign
- ☐ Discontinue

☐ DISCONTINUE DOSIMETER *(no longer needed, likely annual dose less than 100 mrem/yr)*

In Vivo Requirements:
- ☐ Schedule
  - ☐ WB (3-minute whole body count)
  - ☐ WC (10-minute whole body count)
- ☐ Chest
  - ☐ CA (Am-241 , Pu)
  - ☐ CU (U-235 , Th-234)
  - ☐ CC (All)
- ☐ Discontinue In Vivo For: _____

Effective Date: _____
[1] _____ Type Freq Anal. Req.
[2] _____ Type Freq Anal. Req.
Dosimetry Use Only

Excreta Bioassay Requirements:
- ☐ Plutonium
- ☐ Uranium
- ☐ Strontium-90
- ☐ Americium-241
- ☐ Tritium
- ☐ Other _____
- ☐ Discontinue Bioassay for: _____

Effective Date: _____
[1] _____ Iso Req Month Freq Year
[2] _____ Iso Req Month Freq Year
[3] _____ Iso Req Month Freq Year
[4] _____ Iso Req Month Freq Year
Dosimetry Use Only

Home Address *(necessary only for Bioassay delivery)*

_____
Street (If Route, please provide a map)

_____
City *State* *Zip Code*

Remarks:

PNNL Dosimetry Operations: | Date:

A-6000-616 (05/05)

Exhibit 6.2

Explanation For Supplemental "Contractor Request" Bioassay

Worker's Name: _____

Payroll No. or Hanford ID No: _____

The following measurement(s) is requested under the Contractor Request reason code as a one-time supplement to the worker's normal routine (periodic) bioassay monitoring program, or as a stand-alone request for a worker not normally on a routine program. The reason for this supplemental bioassay does not meet the criteria for "Special" bioassay, as defined in the Hanford Internal Dosimetry Program Manual, PNL-MA-552.

Bioassay Analysis	Bioassay Date
_____	_____
_____	_____

Reason for Contractor Request supplementary bioassay:

_____

_____

_____

_____

_____

Results of these measurements will be compared with the corresponding screening levels for similar periodic measurements and investigated only if a screening level is exceeded.

This documentation of a Contractor Request Bioassay will be filed in the worker's permanent radiation exposure file.

Requesting Authority: _____ Date: _____

Send completed form to Hanford Radiation Records Program, MSIN P7-01

Exhibit 6.3 - Sample Form - Bioassay Urine Sample Results

* * * * * * * * * * *

STRICTLY PRIVATE

* * * * * * * * * * *

Date: 07/18/2003 HID:

Name: Org Cd: D9TRP

Dept Id: 118004

Bioassay Examination Report

The analysis of your excreta sample collected on 06/19/2003 has been completed for the following tests: U ISOTOPIC (IU)

Results do not exceed the criteria for follow-up measurement nor do they change previous assessments of internal dose or current bioassay measurement schedules.

Records of this and your other bioassay examinations are maintained in your personal exposure file. Contact your company's radiation protection or radiation dosimetry office on 376-1707 if you have any questions regarding your occupational radiation exposure status.

This statement was prepared by Hanford Internal Dosimetry.

REX-GR10

Exhibit 6.4

PRELIMINARY ANALYSIS OF IN VIVO EXAMINATION

NAME:
PAYROLL:
REASON CODE:
EXAM DATE:

Preliminary analysis of your in vivo examination(s) indicates:

_____ (1) Your in vivo measurements are completed, and the results do not exceed the criteria for follow-up.

_____ (2) Your first in vivo measurement indicated the possible presence of internal radioactivity from occupational sources. However, the results from your second count, usually longer and more sensitive did not indicate the presence of radioactive material from occupational sources. Your first count may have been a false positive result, expected to occur about 5 percent of the time, or caused by other factors including the presence of naturally occurring radon progeny.

_____(3) Final analysis of the examination data is not immediately available. This may be due to a temporary suspension of the analysis portion of the computer software or a need to review the quality of the detection system performance. The results of this examination will be provided to your company's radiation protection organization when available.

_____ (4) Your measurement exceeds a screening level. This can result from a random, statistical fluctuation in the background measured by the detector, very low-level skin contamination, an intake of naturally occurring or medical-related radioactive material not related to your work, or an occupational intake. A further review of the examination will be performed and your radiation protection organization will be notified of the results. Follow-up measurements may be required.

If you have any questions, please contact your radiation protection representative listed below.

Contractor Name:
Contact Name:
Contact Phone:

Please note: This report is based on a preliminary evaluation of your measurement by computer and is subject to change based upon additional review. If there is a change from the above reported results, Personnel Dosimetry will notify your company's radiation protection organization.

Exhibit 6.5 - Sample Letter - In Vivo Measurements Results

STRICTLY PRIVATE

Date: 09/27/2003

Name: IM ATEST
PR No: 12345

IN VIVO EXAMINATION REPORT

The preliminary analysis or subsequent review of your 09/26/03, whole body exam indicated the possible presence of radioactivity, and the possibility of additional measurements may have been discussed with you. A detailed review of the measurement spectrum has since been performed, with the conclusion indicated by the box(es) checked below:

☐ FALSE POSITIVE – Your result does not truly reflect the presence of radioactivity and has been identified as a "false positive" result. The extreme sensitivity of our measurements makes the slight variation in background levels from one person to another sometimes appear as a detected result when analyzed by the computer. An in-depth technical review of the measurement showed interference that the computer interpreted as radioactivity. These false-positive results are a fact-of-life associated with highly sensitive measurements, and are expected in as many as five percent of our measurements.

☐ MEDICAL – The detected radioactivity is associated with medical applications. It could result from a nuclear medicine procedure you had recently, or if you were recently in close contact with someone who had such a procedure. Typical radionuclides in this category include thallium-201, thallium-202, iodine-131, and technetium-99m.

☐ ENVIRONMENTAL – The detected radioactivity is attributed to non-occupational sources.

☐ CONSISTENT WITH PRIOR EVALUATION – The detected radioactivity is consistent with a previously evaluated intake and does not require a new investigation.

☐ BELOW OCCUPATIONAL SCREENING LEVELS – The detected radioactivity could be attributable to occupational intake, but is below the screening levels used for investigation and dose assessment. Any implied doses are below 10 mrem committed effective dose equivalent.

Based on this determination, no further measurements are required and no additional investigation will be performed. Records of this and your other bioassay examinations are maintained in your personal exposure file. If you have questions concerning this, please contact Robert Jones at 376-1707.

Hanford Internal Dosimetry

cc: Radiation Exposure File

HANFORD INTERNAL DOSIMETRY PROGRAM MANUAL
PNL-MA-552

SECTION 7.0, POTENTIAL INTAKE INCIDENT RESPONSE

Issued: 04/07

Supersedes: 10/2003

Use Category: Not applicable

Approval Signatures:

Approved by: Eugene H Carbaugh 4/25/2007
E.H. Carbaugh, Internal Dosimetry Program Manager

Reviewer Signatures:

Reviewed by: Cheryl Antonio
C.L. Antonio, Dosimetrist

Approved by the Hanford Personnel Dosimetry Advisory Committee as recorded in the meeting minutes of January 10, 2007.

7.0 Potential Intake Incident Response

This chapter provides guidance for recommended dosimetry response to incidents of potential radionuclide intake. The roles of the contractor, DOE office, Internal Dosimetry (via the Exposure Evaluator [EE]), and other support groups in obtaining dosimetry data and in performing early assessments of intake are discussed. Also addressed are some EE tasks that are performed under the auspices of the IDP but are not directly related to Internal Dosimetry.

For the purposes of this chapter, a potential intake incident is defined as any circumstance involving loss of containment or administrative control that may result in a worker incurring an intake requiring an internal dose assessment. However, the majority of the material in this chapter is directed toward the circumstance where knowledge of a potential intake is recent (i.e., within one to three days).

7.1 Incident Response Objectives of the Hanford Internal Dosimetry Program

In responding to potential intake incident, the IDP's principal objective is to perform initial and follow-up assessments of the seriousness of the exposure. Such assessments support the DOE office/contractors' reporting and investigating requirements, and address the medical considerations regarding the effectiveness of dose-reduction therapy. In addition to the role in responding to potential intake incidents, the EE provides notification services for other types of incidents at Hanford.

7.2 Incident Response Services Provided By the Hanford Internal Dosimetry Program

The IDP provides incident response by means of its EE function. The EE is a sitewide 24-hour on-call contact for dosimetry and notification assistance.

Internal Dosimetry Services

The following intake assessment services are available through the EE:

- consultation regarding the need for and priority of special bioassay measurements
- arrangements for bioassay measurements and samples
- identification of supplemental measurements and samples to aid in the performance of internal exposure evaluations (e.g., measurement of air filters and smears)
- arrangement with PNNL Radiological Control for Radiological Control Technicians (RCT) support for the IVRRF and offsite medical support facilities.

- initial assessment of the potential severity of intakes based on early data
- discussion with workers about the results of specific measurements (done in conjunction with Field Dosimetry and contractor/DOE office representative)
- arrangement for appropriate follow-up bioassay measurements.

Services Not Related to Internal Dosimetry

The following services, not related to internal dosimetry, are also available through the EE:

- dosimetry assistance for unusual external exposure situations
- request for assistance from PNNL Radiological Control for monitoring potentially contaminated Hanford patients who report to Kadlec Medical Center, other local hospitals or medical facilities, Hanford first aid stations, or the IVRRF.

7.3 Determining the Need for Internal Dosimetry Support

Criteria for EE Notification

Internal Dosimetry should be contacted whenever an intake of radioactivity is suspected, or when the dosimetric significance of an observation or event is in doubt.

The following are examples of circumstances that could warrant contacting Internal Dosimetry:

- abnormal radioactivity detected on nasal smears
- suspected intake of radioactive material with the potential for a CEDE of 100 mrem
- single or cumulative airborne exposures totaling more than 10 DAC-hours in a calendar year, after correction for respiratory protection worn at the time of exposure.
- extended or extensive personal skin contamination
- loss of containment or exposure control, such as failure of a ventilation system or respiratory protection, resulting in exposure to high concentrations of radioactivity in the air
- spread of contamination that results in levels of radionuclides at or exceeding the levels given in Table 7.1
- unplanned releases of radioactive material to the environment that may have affected workers.

It is also recommended that Internal Dosimetry be included on the distribution list for radiation occurrence reports.

Table 7.1 Contamination Levels for Notifying Internal Dosimetry

Indicator	Alpha-Emitters, dpm	Beta-/Gamma-Emitters, dpm
Nasal or mouth smears	Above background	Above background
Facial contamination	200	4,000
Skin breaks	Any skin break while handling alpha-emitters other than sealed sources.	Any detectable activity around or on a skin break; or detectable activity on a blood smear.
Head, neck contamination	2,000	40,000
Contamination inside respirator	Detectable activity inside respirator after use.	
Hands, forearms, clothing[a] (spotty, loose)	10,000	200,000
Airborne contamination after incorporating respiratory protection factor	Acute exposure exceeding 40 DAC-hours[b] should undergo special bioassay. Acute or cumulative exposures exceeding 10 DAC-hours in a calendar year should undergo dose assessment; use DAC-hours or special bioassay as appropriate.	

(a) Clothing contamination levels apply to exposure without respiratory protection, such as contamination levels on personal clothing or inner coveralls while undressing.
(b) DAC-hours = time-integrated exposure to airborne contamination.

Criteria for Notifying Occupational Medicine

Internal Dosimetry recommends that Occupational Medicine be promptly alerted to potential intakes when the criteria of Table 7.2 are exceeded. The primary purpose of this notification is to alert Occupational Medicine to the possibility that dose reduction therapy may be warranted. At the request of the contractor/DOE office, the EE may make this notification. The EE may also informally notify Occupational Medicine if there seems to be a possibility that therapy is warranted.

Table 7.2 Contamination Levels for Notifying Occupational Medicine

Indicator	Alpha-Emitters, dpm	Beta-/Gamma-Emitters, dpm
Nasal or mouth smears	1,000	100,000
Facial contamination	25,000	500,000
Skin Breaks	100	20,000

7.3.1 Notifications for Prompt Intake Assessment and Dose Reduction Therapy

When to Notify the EE

The EE should be notified immediately when prompt actions may be required to evaluate internal exposure. The criteria recommended for immediate notification and request for support are shown in Table 7.1. These criteria are based primarily on Hanford experience, which may be taken as indicators that the CEDE may exceed 100 mrem.

The EE should be notified the same day that intakes or potential intakes occur or are identified to ensure that adequate provision is made to obtain bioassay measurements for dose assessment.

When the criteria of Table 7.1 are not met, it is unlikely that therapeutic actions would be taken based on early bioassay measurements. Bioassay measurements are still needed for dose assessment purposes. In some cases the measurements may not need to be immediate (i.e., same day), but may be scheduled on a priority basis a few days after the potential intake. Under these circumstances, the EE may suggest a delayed measurement protocol in consideration of convenience and cost.

7.3.2 Information to Provide when Notifying the Exposure Evaluator

What Information to Provide

Exhibit 7.1 (at the end of this chapter) provides a summary checklist of information that may be useful to the EE for dosimetry evaluation. The EE Office maintains a telephone log for each separate incident notification, using a form similar to the one shown in Exhibit 7.2.

7.4 Contacting the Exposure Evaluator

How to Contact the EE

Contacting the on-call EE may be done using several methods which are described here. During normal working hours, it should be possible to contact the EE within a few minutes by one phone call. After-hours procedures have been established with the intent that the maximum response time for obtaining EE support should not exceed 40 minutes.

7.4.1 Preferred Method

Call 376-2222

The preferred method of contacting the EE is to call the EE Office on 376-2222. During working hours, Internal Dosimetry staff usually answers the phone. After working hours, the phone is forwarded to the on-call EE's residence. If no answer is obtained, wait 5 minutes and try again. Make at least two attempts, waiting at least 5 minutes between each call. If contact cannot be made by this method, use one of the alternate methods described below.

7.4.2 Alternate Methods

Radio Pager:
Onsite 85-9901
Offsite 376-4190
(9901)

The on-call EE carries a pager that can be activated from a Hanford Site telephone by dialing 85-9901. From an offsite phone, the pager can be activated by dialing 376-4190 and then entering "9901" at the tone. At the cue from the recorded message, enter the phone number for the EE to call. This method is particularly useful after hours if the EE is not at home to answer the EE office number (376-2222). Expect some delay in response to allow the EE to reach a telephone.

If no response is received within 15 minutes, contact the Hanford Patrol Operations Center (POC) or the PNNL Single-Point Contact at the numbers below and request an alternate EE.

Patrol Operations Center or PNNL-Single Point Contact

Both the Hanford Patrol Operations Center (POC) and the PNNL Single-Point Contact have emergency procedures for contacting the EE, including a radio pager and alternate contacts.

Patrol Operations Center:	373-3800
PNNL Single-Point Contact:	375-2400

7.5 Exposure Evaluator Response to Incidents

This section briefly describes the general EE response to a potential intake incident. Details of some example incident response protocols are provided in Appendix E.

7.5.1 Receiving Incident Notification

Upon notification of an incident, the EE initiates an incident telephone log similar to Exhibit 7.2. The initial priority of the EE is to obtain the identification of the workers and the circumstances surrounding the exposure, and to determine the appropriate bioassay measurements. Based on the information provided by the contractor/DOE office and the specific services requested, the EE makes appropriate emergency notifications and arranges for bioassay measurements. The EE then makes a preliminary assessment of the potential effectiveness of therapeutic measures, and identifies additional information that might assist in assessing the significance of the exposure.

The EE Office does not normally report contractor incidents to DOE or Occupational Medicine. The decision to report incidents to DOE or Occupational Medicine is the responsibility of the contractor, unless other arrangements have been made with the EE Office. However, if the probability of intake is considered serious enough to possibly warrant therapy, Occupational Medicine may be informally advised by the EE Office. (Note: These statements should not be construed as restricting the EE Office in any way from responding to requests from DOE or Occupational Medicine regarding the dosimetry associated with an incident.).

7.5.2 Scheduling and Performing Bioassay Measurements

Initial Bioassay Measurements

A variety of bioassay measurements may be requested. Some of the typical reasons for requesting particular bioassay measurements are described in Table 7.3.

The EE arranges to obtain suitable bioassay measurements. The EE also establishes priorities for measurement types and, if necessary, for individuals needing measurements.

In addition to direct in vivo counts, which can be performed within a few hours of the incident, the EE may arrange for rapid processing of excreta samples, which can provide an analytical result within a few hours of

sample delivery to the Lab. With rapid sample processing, analytical sensitivity is sacrificed for quick turn-around time. The purpose of rapid processing is to obtain immediate results to assess the potential need for, or effectiveness of, dose reduction therapy. The EE should determine if trading analytical sensitivity for quick results is appropriate for dosimetry. Circumstances may also warrant rapid processing to provide the contractor with preliminary information.

Follow-Up Bioassay Measurements

Based on initial measurements, the EE determines the need for follow-up bioassay measurements and advises Field Dosimetry of the needed measurements. In some cases, it may be appropriate for the EE to arrange follow-up measurements directly with the worker at the time of the initial measurements. As information becomes available, the EE advises the contractor/DOE office and discusses results with workers, if requested. The intent of the EE function is to work through Field Dosimetry for all but the most pressing worker communications.

Table 7.3 Typical Incident-Response Bioassay Measurements and Their Purposes

Measurement	Purpose
Whole body counts and lung counts	Measure activity present in a person at a specific post-intake time. Multiple measurements are used to establish the specific retention pattern in the person.
Head counts	Estimate skeleton burden of bone-seeking radionuclides. This estimate is used to confirm skeleton deposition and to convert chest count results to lung content by correcting for interference from skeleton activity.
Organ counts or wound count	Measure activity present in a specific organ or tissue at a specific post-intake time. Used to estimate the retention pattern of the individual.
Urine samples approximate 12 h approximate 24 h total	Estimate excretion rate of radionuclides not readily detectable by direct in vivo counting. Internal deposition of such nuclides is estimated based on standard models. Multiple samples may be required to determine the individual excretion patterns and appropriate excretion model.
Urine samples (single voiding or "spot")	Provide initial order-or-magnitude estimate of exposure based on excretion model. This measurement is also suitable for routine and nonroutine tritium dosimetry.
Fecal samples	Confirm intake. Provide isotope identification and ratio information. Estimate dose based on early clearance (may require multiple samples). Differentiate soluble from insoluble materials.

Measurement Protocols

The EE determines measurement protocols for incidents. Some example protocols are included in Appendix E.

7.5.3 Dose Assessment Capability

The dose assessment and reporting practices are described in Chapters 3.0 and 4.0 of this manual. Summary statements are provided here because they are related to incident response.

Dose Sensitivity

The IDP has the capability to assess a CEDE of 100 mrem for all radionuclides of concern at Hanford. In some cases, however, the ability to do so is contingent upon obtaining appropriate bioassay measurements (fecal samples, urine samples, in vivo measurements) within the first few days post-exposure. For most nuclides, if early data are obtained within the first few days following exposure, the dose assessment capability is 10 mrem or less. The exhibits in Chapter 5.0 and Appendix E of this manual describe the capability of bioassay measurements with regard to minimum detectable dose. The Methods & Models of the Hanford Internal Dosimetry Program (PNNL-MA-860) provides additional discussion on the methods of determining the sensitivity.

Preliminary Dose Assessment

An initial assessment of the magnitude of a potential intake and internal dose is made as soon as the data permit. Because the circumstances of each intake are different, initial estimates may be inaccurate. In general, when bioassay measurements confirm an intake, follow-up measurements are required to estimate an internal dose accurately. Early estimates of internal dose should be considered as order-of-magnitude estimates only.

Initial assessments are normally communicated directly to Field Dosimetry without a formal evaluation and transmittal letter. If requested by the contractor/DOE office, a preliminary dose assessment letter is provided.

Final Dose Assessment

Final dose assessments are issued when sufficient data have been obtained to confidently estimate the doses required to be reported to DOE. These dose assessments become part of the permanent REX files.

7.6 Guidance for Exposure Evaluator Response to Incidents

This section provides general guidance for EE responses to some anticipated situations. It is not intended to be an all-encompassing statement of EE response, nor is it intended to replace other contractor, DOE or EE policies, procedures, or requirements.

7.6.1 Managing Uninjured Workers Who Are Externally Contaminated

The incident contractor/DOE office is responsible for the management of externally contaminated uninjured workers. Normally, workers should be decontaminated before being released from the facility. If external contamination is detected on workers at the IVRRF, the EE, RCT, contractor/DOE office, and IVRRF staff must determine the action to be taken. The IVRRF is not used as a decontamination center, and

workers with removable contamination should not be counted until such contamination has been removed.

Clothing or personal items discovered to be contaminated in surveys made at the IVRRF are bagged and dispositioned according to the contractor/DOE office instructions. Normally, the contractor/DOE office radiological controls organization deals with these items.

7.6.2 Managing Injured Workers Who Are Externally Contaminated

The primary responsibility for management of all injured workers, whether contaminated or not, lies with the responding medical authority. This authority may be Occupational Medicine, Kadlec Medical Center, or the Hanford Fire Department ambulance operating under the direction of the Mid-Columbia Emergency Medical Service.

When dealing with contaminated workers, the EE supports medical staff by providing advice in matters of dosimetry for the patients and attending staff. The decontamination of an injured worker is a medical staff responsibility, although the EE or RCT may be requested to assist in the decontamination efforts. Medical staff also determine the priority of medical treatment versus decontamination.

If decontamination efforts fail to completely remove personal contamination, it may be appropriate to release a worker with residual skin contamination. This decision must be made by the contractor/DOE office representative. Under such circumstances, the worker should be advised of appropriate techniques to limit the potential spread of contamination after release.

Such techniques might include the use of shower caps, gloves, or bandages, to provide a barrier against contamination spread. In addition, it is suggested that the worker be advised when spread of contamination would not be a significant concern upon release. Home surveys may be appropriate in some cases, and are the responsibility of the event contractor/DOE office and the worker's employer.

7.6.3 Taking Therapeutic Measures to Reduce Internal Dose

Therapeutic measures to reduce dose are the responsibility of Occupational Medicine. These methods may include the use of various drugs (e.g., diethylenetriamine pentaacetic acid [DTPA], potassium iodide, alginates, or diuretics) and surgical techniques (e.g., minor tissue excision, wound debridement). The EE advises Occupational Medicine of the potential effectiveness of various treatment alternatives to reduce dose, and informs Occupational Medicine of the potential internal dose to patients as subsequent bioassay data become available. Guidance on therapeutic actions and associated intervention levels for bioassay measurements is contained in Appendix E.

7.6.4 Releasing Workers Following an Incident

The initial bioassay measurements that are necessary following an incident should be performed before the worker is released. The personal comfort of a worker is considered if extensive hold-over following a workday has already occurred or if discomfort occurs because of injury or extensive counting times. Actual measurements for the initial worker assessment should not normally require more than about 2 hours at the IVRRF. If more than one worker is involved in an incident, this time could be extended, or workers may be requested to return for additional counts at a later time.

When workers involved in an incident are initially counted or treated, a contractor/DOE office representative should be present. This representative bears the responsibility for release of the workers and for dealing with their questions regarding such items as overtime compensation or when to return. The EE addresses, to the extent that the available data allow, questions about potential internal dose and arranges for necessary excreta samples.

7.6.5 Assisting in External Radiation Exposure Situations

If the contractor/DOE office requests special assistance regarding an external radiation exposure incident or concern, the EE arranges for the Hanford External Dosimetry Program to provide this assistance.

7.6.6 Offsite Assistance Request

If the EE receives a request for assistance from a non-Hanford source, the EE attempts to determine the nature of the requested assistance and to direct the inquiry to the appropriate authority. Specific requests for Hanford services are directed to RL.

7.7 Reference

Pacific Northwest National Laboratory (PNNL). *Methods and Models of the Hanford Internal Dosimetry Program*, PNNL-MA-860. Richland, Washington. (Internal manual.) Available at URL http://www.pnl.gov/eshs/pub/pnnl860.html

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When workers involved in an incident are initially counted or treated, a contractor/DOE office representative should be present. This representative bears the responsibility for release of the workers and for dealing with their questions regarding such items as overtime compensation or when to return. The EE addresses, to the extent that the available data allow, questions about potential internal dose and arranges for necessary excreta samples.

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7.7 Reference

Pacific Northwest National Laboratory (PNNL). *Methods and Models of the Hanford Internal Dosimetry Program*, PNNL-MA-860. Richland, Washington. (Internal manual.) Available at URL http://www.pnl.gov/eshs/pub/pnnl860.html

Exhibit 7.1 Checklist for Incident Data

General Information

- Description of incident—one or two sentences and date and time of incident
- Location of incident (area, building, room)
- Personnel involved (name, payroll number, job title, and address for each person).

Internal Exposure-Related Information

- Retain any object causing contamination for possible investigation
- Radionuclides
- Form of material (wet/dry, chemical form, soluble/insoluble)
- Mode of intake
- Respiratory protection (type, evidence of leakage)
- Nasal, mouth, or blood smear results (dpm)
- Facial contamination level (dpm)
- Other skin contamination (dpm)
- Clothing contamination (dpm)
- Area contamination (dpm)
- Airborne activity concentration (μCi/cc)
- Correlation of contamination levels to potential exposure of worker.

External Exposure-Related Information

- Radionuclides (or type and energy of emission)
- Source activity
- Source geometry
- Estimated dose rate (type of instrument and distance)
- Supplemental dosimetry
- Duration of exposure
- Worker position relative to source
- Shielding around worker
- Shielding around source
- Anticipated delivery of dosimeters for processing.

Criticality Exposure-Related Information

- How detected?
- Number of workers exposed?
- Quick sort performed? Results of gut readings?
- Readings on worker personal effects
  - Item, reading
  - Instrument used, efficiency and background
  - Elapsed time between criticality and reading
- Orientation and distance of worker to critical assembly
- Any immediate symptoms? (describe)
- Fissile material
- Shielding material and thickness
- Current status of area; any chance for recurrence?
- Environmental release?
- Have nuclear accident dosimeters (NADs or "candles") been collected?
- Have worker dosimeters been collected?

Exhibit 7.2 Incident Telephone Log

RADIATION INCIDENT - TELEPHONE REPORT

Date of Report _____ DEMS No. _____
Time of Report _____
Reported by _____ Contractor _____

Employee	Payroll/SS #	Company, Job, address if needed
1.		
2.		
3.		
4.		
5.		

Incident Date _____ Time _____ Bldg. _____ Area _____
Incident Description: Intake ☐ External ☐ _____

Prin. Isotope(s) _____ Mode of Intake _____

Employ. No.		Nasal Contamination Alpha	Nasal Contamination Beta	Skin, Other Personal Contamination
1.	Rt	_____ dpm cpm	_____ dpm cpm	_____
	Lt	_____ dpm cpm	_____ dpm cpm	_____
2.	Rt	_____ dpm cpm	_____ dpm cpm	_____
	Lt	_____ dpm cpm	_____ dpm cpm	_____
3.	Rt	_____ dpm cpm	_____ dpm cpm	_____
	Lt	_____ dpm cpm	_____ dpm cpm	_____
4.	Rt	_____ dpm cpm	_____ dpm cpm	_____
	Lt	_____ dpm cpm	_____ dpm cpm	_____
5.	Rt	_____ dpm cpm	_____ dpm cpm	_____
	Lt	_____ dpm cpm	_____ dpm cpm	_____

Exhibit 7.2 Incident Telephone Log (contd)

ACTIONS TAKEN DTPA 1 2 3 4 5

EE Assigned _____ Worker ☐ ☐ ☐ ☐ ☐

Date/Time _____

In Vivo Counts WBC	Employ. No.	Date Performed	Results
	1		
	2		
	3		
	4		
	5		
Chest Count	1		
	2		
	3		
	4		
	5		

Other Counts (List employee no. and type and results of counts) _____

Excreta	Employ. No.	Type and Sample Date(s)
	1	
	2	
	3	
	4	
	5	

Contractor Rep. Notified: Who _____ Time _____ By _____

External Notified: Who _____ Time _____ By _____

HANFORD INTERNAL DOSIMETRY PROGRAM MANUAL
PNL-MA-552

SECTION 8.0, QUALITY ASSURANCE

Issued: 04/07

Supersedes: 01/2005

Use Category: Not applicable

Approval Signatures:

Approved by: _____ 4/25/2007
E.H. Carbaugh, Internal Dosimetry Program Manager

Reviewer Signatures:

Reviewed by: _____
C.L. Antonio

Approved by the Hanford Personnel Dosimetry Advisory Committee as recorded in the meeting minutes of January 10, 2007.

8.0 Quality Assurance

The quality assurance (QA) and quality control (QC) features of the Hanford Internal Dosimetry Program (HIDP) are summarized in this chapter. The overall quality assurance plan for the HIDP is described in the Radiation and Health Technology Quality Assurance Program Plan, with Appendix B of that plan detailing items specific to the HIDP.

8.1 Quality Assurance and Quality Control for Bioassay Analyses

The quality of analytical results is monitored by the QA and QC programs of the Analytical Services Laboratory (Lab) and the laboratory oversight program of HIDP, the In Vivo Monitoring Program (IVMP), and the Department of Energy (DOE) through its Laboratory Accreditation Program (DOELAP).

8.1.1 DOELAP Accreditation

The HIDP maintains accreditation for indirect radiobioassay analyses through the Department of Energy Laboratory Accreditation Program (DOELAP). The accreditation involves submittal of documentation to DOELAP, triennial performance testing of the analytical laboratory, and an onsite assessment by DOELAP technical assessors. A copy of the accreditation is shown in Exhibits 8.1 and 8.2.

Separate accreditation for direct radiobioassay measurements is maintained by the In Vivo Monitoring Program.

8.1.2 Analytical Services Laboratory

The Lab measures essentially all indirect bioassay samples and is required by contract to maintain rigorous, extensive, well-documented QA and QC programs.

The Lab is required to maintain a QA manual that outlines responsibilities and provides requirements for data control, document control, calibration and checks of maintenance and test equipment, procedures, training, corrective action in the event of noncompliance, and traceability to standardizing bodies such as the National Institute of Standards and Technology (NIST).

The QC program involves analyzing blanks and spiked samples with each batch of real samples, constantly reviewing data, and publishing quarterly and annual QC reports. No less than 15% of all samples processed are blanks and spikes.

The QC samples are used to demonstrate compliance with requirements specified in the contract between the Lab and PNNL. The requirements in the contract are at least as restrictive as, and in some areas more restrictive than, the recommendations in American National Standard

HPS N13.30-1996 (HPS 1996) and DOE Standard DOE-STD-1112-98 (DOE 1998) on performance criteria for radiobioassay testing. These requirements determine detection levels (MDAs) for each radionuclide and matrix, as well as the allowable bias and required precision of the results. The Lab must demonstrate that actual MDAs are no greater than the levels specified in the contract and that bias and precision are within specified limits.

All routine analyses (i.e., not research and procedure development work) must be done according to written and approved procedures. In addition, all analysts must be trained and certified in each procedure before they can routinely perform the applicable analysis.

8.1.3 Internal Dosimetry Oversight of the Lab's Quality Control Program

HIDP conducts an independent oversight program as a check on the validity of the Lab's QC results. The program consists of a combination of blank and spiked samples, which may be submitted for analysis as known audit samples (single blind audits), masked for analysis as authentic worker samples (double blind audits), or split with another laboratory for simultaneous analytical intercomparison (split samples). The results of the audit samples are used to track Lab performance relative to the contractual detection levels in essentially the same manner as the Lab's own QC program. This procedure serves as an additional check on the Lab's ability to meet HPS N13.30-(HPS 1996) recommendations and contract requirements.

The results of HIDP's oversight program are documented quarterly by means of a letter report. Any discrepancies between the results of the Lab's and HIDP's QC data are investigated, and corrective actions are taken as necessary.

8.1.4 Quality Assurance of In Vivo Measurements

The QA of in vivo measurements is detailed in the *In-Vivo Monitoring Program Manual* (PNL-MA-574), and in R&HT Quality Assurance Program Plan (R&HT QAPP). In brief, the program consists of daily equipment calibration and background checks using secondary reference sources and periodic calibrations using primary sources (i.e., NIST-traceable sources) in phantoms. In addition, the IVMP participates in laboratory intercomparison studies, in which spiked phantoms are sent to national and international facilities and the results are compared.

The results of workers' counts are tracked on computer by payroll number and name and are transmitted to the REX database weekly. The QA data are temporarily stored in hard-copy form at the IVRRF library and ultimately transferred to the HRRP. Computer codes are validated and verified according to software test plans.

8.2 Quality Assurance and Quality Control for Dose Assessments

The intention of the HIDP is for internal dose assessments to meet the DOE requirements as stipulated in 10 CFR 835, and the *Internal Dosimetry Program Guide* (DOE 2005). The methods used to assess internal dose are described briefly in Chapter 3.0 of this manual and are addressed more completely in the Methods & Models of the Hanford Internal Dosimetry Program (PNNL-MA-860). Generally, the methods are consistent with those recommended by national and international authorities, such as the ICRP and the NCRP.

All internal dose assessments are performed by the HIDP technical-professional staff and include or reference all methods and data used in the evaluation. Documentation of the assessment should be sufficient to enable a technically qualified health physicist to reconstruct the assumptions, methods, and conclusions of the assessment. Computer codes used for dose assessment are verified and validated according to code-specific software test plans.

Before an internal dose evaluation is issued, it undergoes peer review by a second HIDP technical professional staff member to verify the technical accuracy and completeness. In addition, the evaluation and summary letter must be approved by the HIDP Manager before they are issued.

HIDP staff responsible for dose assessments have basic knowledge of ionizing radiation and ICRP and NCRP guidance on internal dosimetry through either education or training. In addition, they have been trained in methods described in this manual and on the specific computer codes germane to each dose assessment that they perform. Before new dosimetrists are determined ready to perform dose assessments by the HIDP Manager, they undergo a period of apprenticeship commensurate with their experience and education.

8.3 Internal Dosimetry Program Records

The records generated by the HIDP are maintained in files within the Radiation and Health Technology organization. The HIDP manager is responsible for the designation and maintenance of these records. Additional information is provided in Chapter 9.0.

8.4 Assessments of the Internal Dosimetry Program

Quality assurance assessments and management self-assessments are part of the HIDP and are planned and performed as required by the R&HT Quality Assurance Program Plan. These assessments are intended to fulfill the requirements of 10 CFR.830.122 (i), but are not intended to fulfill the requirements of 10 CFR 835.102.

The HIDP is also subject to quality verification assessments by outside organizations in support of their own quality assurance programs and

regulatory compliance efforts, such as the 10 CFR 835.102 requirement for contractor radiation program assessments. The responsibility for planning and conducting such assessments is beyond the scope of the HIDP, lying with the contractor organization governed by the radiation protection program. The HIDP will be responsive to contractor auditing requirements.

8.5 Reference

10 CFR 835. 1999. Department of Energy, *Occupational Radiation Protection.* U.S. Code of Federal Regulations.

Health Physics Society (HPS). 1996. *Performance Criteria for Radiobioassay.* HPS N13.30-1996, McLean, Virginia.

Pacific Northwest National Laboratory (PNNL). *In Vivo Monitoring Program Manual,* PNL-MA-574. Richland, Washington. (Internal manual.)

Pacific Northwest National Laboratory (PNNL). *Methods and Models of the Hanford Internal Dosimetry Program,* PNNL-MA-860. Richland, Washington. (Internal manual.) Available at URL http://www.pnl.gov/eshs/pub/pnnl860.html.

Pacific Northwest National Laboratory (PNNL). *"R&HT Quality Assurance Program Plan."* Richland, Washington. (Internal document.)

U.S. Department of Energy (DOE). 1998. *DOE Standard Department of Energy Laboratory Accreditation Program for Radiobioassay.* DOE-STD-1112-98, Washington, D.C.

U.S. Department of Energy (DOE). 2005. *Internal Dosimetry Program Guide.* DOE G441.1-3A, Washington, D.C.

Exhibit 8.1 Certificate of DOELAP Accreditation for Hanford Indirect Radiobioassay

Exhibit 8.2 Conditions of DOELAP Accreditation for Hanford Indirect Radiobioassay

CONDITIONS OF DOELAP ACCREDITATION

Hanford Site

Effective until August 31, 2007, the radiobioassay systems described below, used at the Hanford Site, are granted DOELAP accreditation:

DOELAP Categories (In-direct Bioassay):

		Urine Matrix	Fecal Matrix
I.	Low Energy Beta, ^{3}H	✓	
II.	High Energy Beta, ^{90}Sr	✓	✓
III.	Alpha Activity, Isotopic Analysis		
	$^{228/230}Th$, ^{232}Th	✓	✓
	$^{234/235}U$	✓	✓
	^{238}U	✓	
	^{238}Pu	✓	✓
	$^{239/240}Pu$	✓	✓
	^{241}Am	✓	✓
	^{237}Np	✓	
IV.	Elemental Uranium	✓	
V.	Gamma		
	^{137}Cs	✓	✓
	^{60}Co	✓	✓

DOELAP Categories (Direct Bioassay):

		Type	System
I.	Transuranic Elements, L X-Rays	Lung	Iron, SS
II.	Americium, ^{241}Am	Lung	Iron, SS
III.	Thorium, ^{234Th}	Lung	Iron, SS
IV.	Uranium, ^{235}U	Lung	Iron, SS
V.	Fission and Activation Products	Lung	Palmer
VI.	Fission and Activation Products	Total Body	Palmer, Stand-Up

Accreditation is for these radiobioassay programs only and is contingent upon maintaining radiobioassay practices that are consistent with the methodologies used during DOELAP performance testing and the onsite assessment.

HANFORD INTERNAL DOSIMETRY PROGRAM MANUAL
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SECTION 9.0, DOCUMENTS AND RECORDS

Issued: 04/07

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Approval Signatures:

Approved by: Eugene H Carbaugh Apr/25,2007
E.H. Carbaugh, Internal Dosimetry Program Manager

Reviewer Signatures:

Reviewed by: C.L. Antonio
C.L. Antonio

Approved by the Hanford Personnel Dosimetry Advisory Committee as recorded in the meeting minutes of January 10, 2007.

9.0 Documents and Records

The Hanford Internal Dosimetry Program (HIDP) is described by and operated in accordance with numerous documents. A variety of records are created and managed by the operation of the HIDP. Many of those records are subject to provisions of the Privacy Act (1979). This section provides a brief description of the types of documents and records important to the program. The Records Inventory and Disposition System (RIDS) index, maintained by the Program Manager, provides the details on record identification, storage, custodianship, retention periods, and disposition. Repositories for these documents include the program records files, the Hanford Radiation Records Program (HRRP), the Hanford Historical File (maintained by the HRRP), worker personal radiation exposure files (maintained by HRRP), the PNNL Total Records Information Management (TRIM) electronic records management system, and the Department of Energy Holding Area. Information concerning these documents and records is available from the HIDP Manager.

A moratorium on the destruction of all records generated under the PNNL 1830 contract is in effect. Due to pending litigation the Department of Energy has directed Battelle-PNNL to cease the destruction of 1830 contract records. This includes records that have met their retention requirements, whether they are maintained in offices or have been sent to storage.

9.1 Descriptive Program Documents

Descriptive program documents provide the technical and administrative basis on which the HIDP is founded, and the implementing procedures by which it is run. Examples of these documents include manuals, quality assurance plans, program management documents, reports, correspondence, computer codes and their manuals, procedures, and similar implementing instructions, guidance, and reports. The following documents are of particular importance:

- *Methods and Models of the Hanford Internal Dosimetry Program,* PNNL-MA-860. This manual describes the science and assumptions used by the HIDP. It includes technical methods, supporting evidence, and reference information. The target audience for this document is the technical staff directly supporting the program. The manual is available online at http://www.pnl.gov/eshs/pub/pnnl860.html.

- *Hanford Internal Dosimetry Program Manual,* PNL-MA-552. This manual describes the services and capabilities provided by the HIDP, including its operating practices, recommendations for

good practice, general guidance to users, and statements of bioassay capabilities. The target audience for this document are the clients of the HIDP. The manual is available online at http://www.pnl.gov/eshs/pub/pnl552.html.

- *Hanford Internal Dosimetry Procedures Manual,* PNL-MA-565. This manual is a compilation of the procedures for the day-to-day operations of the HIDP, including data reviews, communications, evaluation documentation, and records management.

- *Radiation and Health Technology Quality Assurance Program Plan.* This is the quality assurance manual under which the HIDP operates. The numbered sections of the manual apply to all activities within the PNNL Radiation and Health Technology group. Appendix B to this plan describes those quality provisions specific to the HIDP.

- *Analytical Laboratory Contract and Statement of Work (SOW).* The SOW provides the technical requirements for contractual performance by the excreta bioassay analytical support laboratory. The contract is between Battelle Memorial Institute and the supporting laboratory, and is technically administered through the HIDP.

- *In Vivo Monitoring Program Manual* (PNL-MA-574). This document provides the technical basis for the In Vivo Monitoring Program (IVMP) that performs all in vivo measurements at Hanford. The IVMP is managed independently of the HIDP. It is included here for completeness in identification of program documents directly relevant to internal dosimetry at Hanford.

- *On-Call Exposure Evaluator Manual* (PNL-MA-857). This manual is a compilation of technical information, forms, and call lists that can be used in combination with professional judgment when an on-call exposure evaluator responds to requests for assistance. Its distribution is generally limited to those specifically trained as on-call exposure evaluators.

9.2 Radiological Records (Dosimetry Records)

Radiological records, as used in this discussion, are those records that are maintained in a worker's personal radiation history file or in the electronic database (i.e., REX) supporting such records. These records typically (but not always) contain data subject to the Privacy Act and are routinely marked "Strictly Private" in accordance with PNNL policy or "Strictly Private – Sensitive" in response to some contractor requirements. Some examples of these records include:

- Final bioassay results for excreta or in vivo measurements
- Bioassay notification letters
- Internal dose evaluations for specific workers
- Contractor Supplemental Bioassay Requests
- In Vivo Exam Questionnaires

9.3 Ancillary Documents

A variety of ancillary documents are generated as part of the routine program operations. These documents include record and nonrecord material, both with and without Privacy Act implications. These documents may be contractually required reports, documents created for routine process monitoring, quality problem reports, management or quality assessments, analytical laboratory vendor documents (e.g., procedures, incident reports), quality oversight or technical reports, or measurement data leading to final results (e.g., measurement spectra, sample process sheets, data reduction calculations, QA/QC/management reviews).

These documents also include the minutes of the Hanford Personnel Dosimetry Advisory Committee, which provides a forum for addressing site-wide dosimetry issues and documenting conclusions. The record copy of these minutes is maintained by the HRRP. The HIDP maintains convenience copies for reference.

Where documents are required as records, the disposition of them is specified in the RIDS. Documents generated for convenience are disposed of at the discretion of the staff generating them.

9.4 References

Pacific Northwest National Laboratory (PNNL). *Hanford Internal Dosimetry Program Manual*, PNL-MA-552. Richland, Washington. (Internal manual) Available online at URL http://www.pnl.gov/eshs/pub/pnl552.html

Pacific Northwest National Laboratory (PNNL). *Hanford Internal Dosimetry Procedures Manual*, PNL-MA-565. Richland, Washington. (Internal manual)

Pacific Northwest National Laboratory (PNNL). *In Vivo Monitoring Program Manual* (PNL-MA-574). Richland, Washington. (Internal manual)

Pacific Northwest National Laboratory (PNNL). *On-Call Exposure Evaluator Manual* (PNL-MA-857). Richland, Washington. (Internal manual)

Pacific Northwest National Laboratory (PNNL). *Methods and Models of the Hanford Internal Dosimetry Program*, PNNL-MA-860. Richland, Washington. (Internal manual) Available online at URL http://www.pnl.gov/eshs/pub/pnnl860.html.

Pacific Northwest National Laboratory (PNNL). *Radiation and Health Technology Quality Assurance Program Plan.* Richland, Washington. (Internal manual)

Privacy Act. 44 *Federal Register,* 510772 (1979).

10.0 References

10 CFR 835. 1993. Department of Energy, *Occupational Radiation Protection*. U.S. Code of Federal Regulations.

Brodsky, A. 1980. "Resuspension Factors and Probabilities of Intake of Material in Process" (or 'Is 10-6 a Magic Number in Health Physics?')." *Health Physics* 39(6):992-1000.

Health Physics Society (HPS). 1996. *Performance Criteria for Radiobioassay*. HPS N13.30-1996, McLean, Virginia.

Health Physics Society (HPS). 1997. Internal Dosimetry for Mixed Fission and Activation Products. HPS N13.42-1997, McLean, Virginia.

Health Physics Society (HPS). 1999. *American National Standard Practice for Occupational Radiation Exposure Records Systems*. ANSI\HPS N13.6-1999, McLean, Virginia.

International Commission on Radiological Protection (ICRP). 1974. *Report of Task Group on Reference Man*. ICRP Publication 23, Pergamon Press, New York, New York.

International Commission on Radiological Protection (ICRP). 1979. *Limits for Intakes of Radionuclides by Workers*. ICRP Publication 30, Parts 1, 2, 3, 4, and Supplements, Pergamon Press, New York, New York.

International Commission on Radiological Protection (ICRP). 1986. *The Metabolism of Plutonium and Related Elements*. ICRP Publication 48, Pergamon Press, New York.

Johnson, J. R., and R. C. Myers. 1981. "Alkaline Earth Metabolism: A Model Useful in Calculating Organ Burdens, Excretion Rates, and Committed Effective Dose Equivalent Conversion Factors." *Radiation Protection Dosimetry* 1(2):87-95.

Jones, S. R. 1985. "Derivation and Validation of a Urinary Excretion Function for Plutonium Applicable Over Tens of Years Post Uptake." *Radiation Protection Dosimetry* 11(1):19-27.

National Council on Radiation Protection and Measurements (NCRP). 1987. *Use of Bioassay Procedures for Assessment of Internal Radionuclide Deposition*. NCRP Report No. 87, Bethesda, Maryland.

Privacy Act, 44 *Fed. Reg.* 510772 (1979).

Sula, M. J., E. H. Carbaugh, and D. E. Bihl. 1991. *Technical Basis for Internal Dosimetry at Hanford*. PNL-6866, Rev. 1, Pacific Northwest Laboratory, Richland, Washington.

U.S. Department of Energy – Richland Operations Office (RL). 1993. *Hanford Site Services Handbook*. RL 1400.1, Richland, Washington.

U.S. Department of Energy (DOE). 1999a. *Implementation Guide for Internal Dosimetry Program Guide*. DOE G 441.1-3, Washington, D.C.

U.S. Department of Energy (DOE). 1999b. *DOE Standard Internal Dosimetry*. DOE-STD-1121-98, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1988. Limiting Values of *Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*. Federal Guidance Report No. 11. Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1988. *Criteria for Establishing a Tritium Bioassay Program*. NRC Regulatory Guide 8.32, U.S. Government Printing Office, Washington, D.C.

U.S. Nuclear Regulatory Commission (NRC). 1992. "Radiation Dose to the Embryo/Fetus." NRC Regulatory Guide 8.36, U.S. Government Printing Office, Washington, D.C.

Watson, E. C., and D. R. Fisher. 1987. *Feasibility Study on a Data-Based System for Decisions Regarding Occupational Radiation Protection Measures*. NUREG/CR-4856, PNL-6137, Pacific Northwest Laboratory, Richland, Washington.

Appendix A. Oral Reporting and Screening Levels for Bioassay Measurements

This appendix lists the levels of routine bioassay measurement results that initiate response by Internal Dosimetry, according to practices discussed in Chapter 2.0. The bioassay measurement laboratories provide prompt verbal notification to Internal Dosimetry for any results that exceed the oral reporting level. Results reported to Internal Dosimetry are compared with the screening levels in Tables A.1 through A.4 to determine if additional investigation or initiation of the dose assessment process is required.

Oral reporting levels (ORL) are specified in the bioassay laboratory statement of work. For excreta samples processed using routine processing codes, the ORL is a numerical value determined as specified in Tables A.1 through A.4. All excreta samples processed using priority, expedite, or emergency processing codes are reported verbally or electronically to Internal Dosimetry. The ORL for any in vivo measurement is the detection of any radionuclide other than ^{40}K, ^{208}Tl, or ^{214}Bi.

Individual-specific screening levels may be established for workers with unusual background levels due to environmental sources or long-term detectable levels resulting from an assessed intake. Such levels are established by the dose assessment process and documented in the resulting evaluations.

Screening levels for bioassay measurements are listed as follows:

Table A.1	Transuranics and ^{90}Sr Urinalysis
Table A.2	Tritium Urinalysis
Table A.3	Uranium Urinalysis
Table A.4	In Vivo Measurements

Table A.1. Transuranic and ^{90}Sr Urinalysis Oral Reporting and Screening Levels and Their Basis

Bioassay Measurement	Oral Report Level, dpm	Screening Level, dpm	Basis for Screening Level
Routine urine analysis results (per approximate 24-h sample unless noted)			
^{238}Pu (IPU)	$>L_c$ (b)	> ORL	Detected activity (a)
$^{239+240}Pu$ (IPU)	$> L_c$ (b)	> ORL	Detected activity (a)
$^{239+240}Pu$ (IPUL)	$> L_c$ (b)	> ORL	Detected activity (a)
^{241}Am	$> L_c$ (b)	> ORL	Detected activity (a)
^{242}Cm	$> L_c$ (b)	> ORL	Detected activity (a)
$^{243+244}Cm$	$> L_c$ (b)	> ORL	Detected activity (a)
^{90}Sr	5	> ORL	Detected activity (a)

(a) Any result greater than the oral reporting level (> ORL) indicates that a CEDE could potentially exceed 10 mrem.

(b) For alpha spectroscopy procedures, the oral reporting level is determined according to the following formula: $L_c = 2*TPU$, where TPU (total propagated uncertainty) = the sample specified estimate of the overall uncertainty associated with the analytical result.

Table A.2. Tritium Urinalysis Oral Reporting and Screening Levels and Their Basis

Tritium Measurement	Oral Reporting Level, dpm/ml	Screening Level, dpm/ml	Basis for Screening Level
Baseline	10	> ORL	Detected activity[a]
400-Area Baseline	10	40	Elevated 400 Area background
Multiple Acute Scenario			
Biweekly Routine	10	110	10 mrem CEDE[b]
Monthly Routine	10	80	10 mrem CEDE[c]
Supplemental Monthly	10	800	100 mrem CEDE[d]
Chronic Equilibrium		310	10 mrem
Single Acute Scenario, Days Post-Intake:			10 mrem/intake
1	10	7,400	
2	10	6,900	
3	10	6,400	
7	10	4,900	
14	10	3,000	
30	10	990	
Single Acute in Addition to a 10-mrem Chronic Average, Days Post-Acute Intake:			20-mrem total
1	10	7,700	
2	10	7,200	
3	10	6,700	
7	10	5,200	
14	10	3,300	
30	10	1,300	

(a) Indicates past tritium exposure. The potential source and dose need to be considered for possible inclusion in the lifetime dose estimate.

(b) Assumes 26 equally spaced intakes per year to give 10 mrem CEDE. No consideration is given to buildup of tritium levels in urine.

(c) Assumes 12 equally spaced intakes per year to give 10 mrem CEDE. No consideration is given to buildup of tritium levels in urine.

(d) Dose could potentially exceed 100 mrem; therefore, a change to biweekly sampling is recommended for closer monitoring until results fall below the biweekly screening level.

Table A.3. Uranium Urinalysis Oral Reporting and Screening Levels and Their Basis

Uranium Measurement	Oral Reporting Level	Screening Level	Basis for Screening Level
Isotopic Uranium (IU) (approximate 24-h sample)			
^{238}U	0.15 dpm	0.15 dpm	Background level
$^{233+234}U$	0.16 dpm	0.16 dpm	Background level
^{235}U	0.007 dpm	0.007 dpm	Background level
Insoluble Uranium Elemental Mass Analysis, (U)			
approximate 24-h	0.2 μg	0.2 μg	Background level
approximate 12-h	0.2 μg	0.2 μg	Oral reporting level [a]
Single void	Any result	0.14 μg/L[b]	Background level
Infrequent (single acute) Exposure Potential, (approximate 24-h sample)			
Quarterly – Elemental Uranium Mass	0.2 μg	0.5 μg[c]	10-mrem CEDE
Quarterly – Isotopic Uranium			
^{238}U	0.15 dpm	0.37 dpm	10-mrem CEDE
$^{233+234}U$	0.16 dpm	0.40 dpm	for mixture [c]
^{235}U	0.007 dpm	0.017 dpm	
Quarterly Supplemental	0.2 μg	2.5 μg	Chemical toxicity[d]
ICP/MS Analysis for ^{236}U	50 pg	> ORL	Detected activity[e]

(a) The oral reporting level is contractually the same as for approximate 24-hour samples. The screening level for 12-hour samples is numerically the same as for 24-hour samples, but extrapolation to a daily excretion implies a less sensitive daily screening level of 0.4 μg/d.

(b) Based on background level of 0.2 μg/d divided by Reference Man daily urine excretion rate of 1.4 L/d.

(c) Assumes 0.3μg from a 2.5 mg class W, 5-μm inhalation plus 0.2μg from environmental background, interpreted as natural uranium.

(d) Levels shown indicate a potential acute intake at one-third of the assumed threshold for acute chemical toxicity.

(e) Based on detection of ^{236}U which is reactor produced and not present in natural uranium.

Table A.4. Oral Reporting and Screening Levels for Routine In Vivo Bioassay Measurements and Their Basis

Bioassay Measurement	Oral Reporting Level	Screening Level	Basis for Screening Level
Baseline and Annual Whole Body Exam			
^{40}K	200 nCi	200 nCi	Environmental[a]
^{60}Co (as class Y)	> L_c	4 nCi	10 mrem CEDE[b]
^{137}Cs (as mixture indicator)	> L_c	> ORL	Detected activity[c]
^{137}Cs (pure nuclide)	> L_c	20 nCi	10 mrem CEDE[b]
^{152}Eu	> L_c	4 nCi	10 mrem CEDE[b]
^{154}Eu	> L_c	3 nCi	10 mrem CEDE[b]
^{208}Tl	0.46	> ORL	Environmental radon
^{214}Bi	6.4	> ORL	Environmental radon
Other Radionuclides[d]	> L_c	> ORL	Unknown source
Chest Count			
Any Radionuclide[d]	> L_c	> ORL	Unknown source
Thyroid Count (quarterly frequency using germanium detector)			
^{125}I	> L_c	5 nCi	10 mrem CEDE[e]

(a) Potassium-40 in the general public normally ranges up to about 200 nCi.
(b) Assumes one year post intake.
(c) Any result > ORL indicates a CEDE could potentially exceed 10 mrem.
(d) Excluding known medical administrations.
(e) Based on potential exposure each quarter with a possible dose of 2.5 mrem each quarter.

Appendix B. Key to Selected Field Codes Used in the Radiation Exposure (REX) Database

This appendix provides an explanation of selected data field codes used in the Radiation Exposure (REX) database that are pertinent to the Hanford Internal Dosimetry Program. The REX database includes online helps which provide an interpretive key to the fields. The listings in this appendix are not necessarily complete or current; they are provided for use when computer access may not be readily available, such as when reviewing hardcopy printouts or reports. The most current listings can be obtained directly from REX, or by contacting the Hanford Radiation Records Program database administrator.

Table B.1. Contractor Codes

Code	Contractor
AA	DuPont, General Electric, ITT Support Services
BB	Isochem, Atlantic Richfield, and Rockwell Hanford Operations
BE	Bechtel Hanford
BN	Bechtel National Corporation
BP	Babcock and Wilcox Protec, Inc.
BW	Babcock and Wilcox Hanford Company
CH	CH2M-Hill Hanford Group
CM	Environmental Management Operation (PNL)
CO	Corps of Engineers
DE	DOE (Early service crew, FBI, Army, BPA, AEC, ERDA, etc.)
DN	Duke Engineering & Services Northwest
DS	Duke Engineering & Services Hanford
DY	Dyncorp Hanford
FD	Fluor Hanford
FH	DuPont, General Electric, ITT Support Services
FL	Fluor Daniel Northwest Services
FN	Fluor Federal Services
HF	Hanford Environmental Health Foundation
HH	Douglas United Nuclear, United Nuclear Industries, UNC Nuclear Industries
KE	Kaiser Engineers Hanford
KK	All-Vitro Engineering Division, Braun Hanford Company
LM	Lockheed Martin Hanford Company
LS	Lockheed Martin Services, Inc.
NH	Numatec Hanford, Inc.
PN	Battelle - PNNL
PP	Energy Northwest
PS	Protection Technology Hanford
QC	Quality Control
RF	Duratek Federal Services Northwest
RR	Kaiser
RS	Duratek Federal Services of Hanford
SU	Cogema Engineering Corporation
TT	JA Jones Construction, George A. Grant, Combustion Engineering, subcontractors
US	US West
VV	Westinghouse Hanford Company (WADCO/HEDL)
W	Multiple Hanford Contractors

Table B.2. Sample Type Codes

Code	Type of Sample
B	Blood
F	Feces
S	Sputum
T	Tissue
U	Urine

Table B.3. Bioassay Measurement Reason Codes for the REX System

Code	Name	Description
BL	Baseline	Measurement is performed to establish a reference level against which subsequent measurements will be compared. Generally, this may be for new employees, or for established employees, prior to commencing work with radioactive materials, beginning a specific type of radiation zone work, or making an offsite trip where potential intakes could occur.
PR	Periodic	Measurement is performed at a regularly scheduled interval.
EA	End of Assignment	Measurement is performed following completion of specific work assignment, but not end of employment.
SP	Special	Measurement is performed as part of a specific investigation of potential internal dose. May include response to off-normal work conditions, or follow-up of abnormal periodic measurements.
CR	Contractor Request	Measurement requested by employer for reasons other than periodic, baseline, end of assignment, or special investigation.
RA	Reanalysis A	First repeat in vivo measurement or second aliquot analysis of an excreta sample.
RB	Reanalysis B	Second repeat in vivo measurement or third aliquot analysis of an excreta sample.
RC	Reanalysis C	Third repeat aliquot analysis of an excreta sample.
R1	Recount 1	First recount of original excreta sample or repeat in vivo exam.
R2	Recount 2	Second recount of original excreta sample or repeat in vivo exam.
QR	Quality and Research	Measurement performed as part of quality control, quality assurance, or research work.
TM	Termination	Final bioassay at termination of employment.
12	Contract Work	In vivo measurement performed under contract to customers rather than for Hanford employees.
20	Source Count	In vivo source count made for system calibration or as a function check, usually using a known check source.
30	Background Count	In vivo system background measurement performed for system calibration or as a functional check.

Table B.4. Excreta Sample Kit Codes

Kit Code* D/R	Kit Code* P/U	Media	Sample Description
1	P	Urine	Approximate 24-hour urine collection. Collected at home over a 2-day period. Used for routine sampling and when a larger volume sample is desired. Designated sample date is the day after kit delivery to the employee.
2	Q	Urine	Approximate 12-hour urine collection for termination sampling only. Collected at home overnight. Designated sample date is the day after the date of kit delivery to the employee.
3	R	Urine	Total 24-hour urine collection. Collected at home and at work (if necessary) to collect all urine voided during a 24-hour period. Generally used for sampling immediately following an occurrence or for work restriction sampling. Designated sample date is the day after delivery or the date on which the sample collection began.
4	S	Urine	Single void (spot urine) collection. Collection in a single bottle, used for initial indications of an intake or when small sample volumes are adequate. Designated sample date is the date of voiding.
5	T	Feces	Collection of a single fecal voiding usually for investigation of a potential intake. Sample date is the day after kit delivery or date on which the sample was voided.
6	U	Urine	Partial day or approximate 12-hour collection. Usually collected at home overnight. Used for collection following an occurrence or when a large volume urine sample is not necessary. Designated sample date is the date of delivery to the employee.
7	V	Urine	Approximate 12-hour collection Sunday-Monday sample (Friday delivery only). Generally used for workers chronically exposed to soluble uranium. Designated sample date is the Sunday in the sampling period.
8	W	Feces	Collection of a single fecal voiding used for a special program for plutonium oxide workers. Designated sample date for shift workers is the Tuesday of long shift change, and for day workers is the appropriate Sunday.
9	X	Urine	Kit designed for collection of urine outside the local service area. Transportation is handled by private carrier. Generally used for termination samples not collected locally.
A	Y	Urine	Simulated 48-hour urine collection. Collected at home over a 4-day period. Used for IPUL sampling. Designated sample date is two days after kit delivery to the employee.
B	Not Applicable	Urine	12-hour urine collection for termination sampling only. Collected at home overnight. Kit delivered in normal manner, but brought to a designated on-site location by worker for pick-up by Contractor. Designated sample date is the day after the date of kit delivery to the employee. Delivery Only, no home pick-up required.

*D/R = Delivery and Retrieval
*P/U = Pick-Up only

Table B.5. Excreta Processing Codes and No-Sample Codes

Processing Code	No-Sample Code	Description
R		Routine processing
P		Priority processing
X		Expedite processing
E		Emergency processing
	CS	Cancelled sample/analysis
	CT	Sample lost due to bioassay analysis contract termination
	FA	Failed Analysis. A valid analytical result could not be obtained
	IS	Insufficient sample. Sample provided by worker but volume insufficient to meet contractual requirements
	LC	Lost container. Sample kit not retrieved
	ND	Not delivered. Sample scheduled but kit never delivered
	NE	Not evaluated - Sample was collected but not analyzed. Typically used when a backup sample was obtained but analysis was determined to be unnecessary and the sample discarded.
	NS	No sample. Kit retrieved but no sample provided by worker
	WW	Waived excreta exam

Table B.6. Codes for Units

Code	Description of Units
01	dpm/sample
02	dpm/volume analyzed
03	µg/l until 07-01-82 µg/sample after 07-01-82
04	µg/gram until 07-01-82 µg/sample after 07-01-82
05	µCi/l
06	µCi/l
07	nCi (nanocuries)
08	µCi (microcuries)
09	dpm/ml

Table B.7. Isotope Codes

Note: This listing is substantially abbreviated. Check the on-line REX help feature for a complete listing. List includes both request and result codes.

Isotope Code	Multiple Result Code	Isotope	Multiple Result Code
AM241		MN 54	
C 14		NP237	
CE144		PB210	
CM242		PM147	
CM244		PO210	
CS137		PU	Plutonium – Alpha
CO 60		PUMIX	Plutonium – Mixture
EU154		PU238	
EU155		PU239	
EU156		PU240	
GS		PU241	
H 3		PU242	
I 131		QUS	
IAM	A	RA224	
IPIU	B	RA226	
ACS	C	RA228	
ICM	D	RND	Radon & Daughters
UMS	E	RU106	
IEU	F	SR	
IPA	J	S 35	
IPS	P	SR 89	
IPSA	L	SR 90	
IPSR	M	TAC	
IPU	Q	TC 99	
IPUB	N	TH227	
IPUBA	Z	TH228	
IRA	R	TH230	
IR192		TH232	
ISCP	S	TH234	
ISPEC	W	U	
ISR	Y	U DEP	
ITH	T	U NAT	
ITPAC	K	U 233	
IU	U	U 235	
IPUL	G	U 238	
IUPU	O	U MIX	
K 40		US	
LEPD	*	ZN 65	
MFP		ZR95	

Note: This listing is substantially abbreviated. Check the on-line REX help feature for a complete listing. List includes both request and result codes.

Table B.8 Excreta Analysis Type and Multiple Result Codes for Excreta Samples

Analysis Type	Multiple Result Code	Analysis Code	Results Reported
Pu isotopic	Q	IPU	^{238}Pu, ^{239,240}Pu
Gamma Spectroscopy	W	ISPEC	^{40}K, ^{137}Cs, and others
Gamma Spectroscopy	*	LEPD	^{241}Am
Sequential Pu Isotopic, Am Isotopic, Cm	K	ITPAC	^{238}Pu, ^{239,240}Pu, ^{241}Am, ^{244}Cm, ^{242}Cm
Sequential ^{90}Sr, Ce, Pm	S	ISCP	^{90}Sr, ^{144}Ce, ^{147}Pm
Sequential Sr-Total, Ce, Pm	I	SCP	Sr, ^{144}C, ^{147}Pm
Cm Isotopic	D	ICM	^{244}Cm, ^{242}Cm, and others
Eu Isotopic	F	IEU	^{152}Eu, ^{154}Eu, ^{155}Eu
U Isotopic	U	IU	^{233,234} U, ^{235}U, ^{238}U
Sequential Pu, ^{90}Sr	P	IPS	^{238}Pu, ^{239,240}Pu, ^{90}Sr
Sequential Pu Isotopic, ^{241}Am	J	IPA	^{238}Pu, ^{239,240}Pu, ^{241}Am
Sequential Pu Isotopic, Sr-Total	M	IPSR	^{238}Pu, ^{239,240}Pu, Sr
Sequential Pu Isotopic, Sr-Total, ^{241}Am	L	IPSA	^{238}Pu, ^{239,240}Pu, Sr, ^{241}Am
Sr Isotopic	Y	ISR	^{89}Sr, ^{90}Sr
Pu Isotopic, ^{241}Pu	N	IPUB	^{238}Pu, ^{239,240}Pu, ^{241}Pu
Pu Isotopic, ^{241}Pu, ^{241}Am	Z	IPUBA	^{238}Pu, ^{239,240}Pu, ^{241}Pu, ^{241}Am
Pu Isotopic/U-Natural	O	IUPU	^{238}Pu, ^{239,240}Pu, U
Pu Isotopic/U-Isotopic	B	IPIU	^{238}Pu, ^{239,240}Pu, ^{234}U, ^{235}U, ^{238}U
U-Natural (soluble)	H	QUS	U
Th Isotopic	T	ITH	^{228}Th, ^{230}Th, ^{232}Th
Ra Isotopic	R	IRA	^{224}Ra, ^{226}Ra
Sequential Am and Cm Isotopic		ACM	^{241}Am, ^{242}Cm, ^{243,244}Cm
Low-level Isotopic Pu	G	IPUL	^{238}Pu, ^{239,240}Pu
Sequential Ac and Th	C	ACS	^{227}Ac, ^{227}Th

Table B.9. Bioassay Frequency Codes

Code	Frequency of Bioassay
A	Annual
B	Biennial (every 2 years)
D	Special Day
F	Five years
Q	Quarterly
S	Semiannual
M	Monthly
W	Weekly
X	Biweekly (every 2 weeks)

Table B.10. In Vivo Body Location Codes

Code	Body Location
ABD	Abdomen
CA1	Chest - Am
CA2	Chest – Am corrected by ultrasound
CC1	Chest – combination (Am, Uranium)
CC2	Chest – combination (Am, Uranium) Corrected by ultrasound
CHT	Chest result
CH1	Chest result
CH2	Chest result corrected by ultrasound measurement of chest wall thickness
CU1	Chest - ultrasound
CU2	Chest – uranium corrected by ultrasound
HND	Hand
KNE	Knee
LG1	Lung result. (Chest result corrected for skeleton burden interference)
LG2	Lung result. (Chest result corrected for skeleton and liver burden interference)
LV1	Liver
LV2	Liver result corrected for skeleton burden interference
LV3	Liver result corrected for skeleton and lung burden interference
LYM	Lymph nodes
SK1	Skeleton result based on a head count
SK2	Skeleton result based on something other than a head count
SPL	Special
THX	Thorax
THY	Thyroid
TRY	Throat
WBD	Whole body
WND	Wound

Table B.11. In Vivo Detector Codes[a]

Code	Type of Detector or Counting Cell
Codes Typically in Use as of August 2003	
CC	Coax GE counter for high resolution whole body counts
DS	Stainless steel room with digital signal processing
LD	Lead Room for special counting geometry
CH	Lead Room special counts
SU	Stand-up whole body count for screening
SS	Stainless Steel Room Lung Count
IR	Iron Room Counter for Lung Count

(a) The current and historical listing of in vivo detector codes is maintained by the InVivo Monitoring Program. The listing provided in this manual is not necessarily current or complete. For the most current information, contact the InVivo Monitoring Program Manager.

(b) IG = Intrinsic germanium.

Table B.12. In Vivo Schedule-Type Codes

Code	Type of Measurement
C	Chest count
C2	Extended chest count
HC	Head and chest count
HD	Head count
H2	Head and extended chest count
LC	Liver and chest count
LV	Liver count
LY	Lymph node count
TC	Thyroid and chest count
TH	Thyroid count
WB	Whole body count
WC	Coaxial germanium whole body count
WD	Wound count

Table B.13 In Vivo Analysis Request Codes

Code	Analysis Performed
CA	Chest count for ^{241}Am only
CC	Chest count for combination of ^{241}Am, ^{235}U, and ^{234} Th.
CU	Chest count for uranium ^{235}U and ^{234} Th

Table B.14. In Vivo No-Result Codes

Code	Reason For No Results
C	External contamination other than radon detected on the subject. Measurement invalid; no results obtained.
F	Failure of equipment or faulty setup of equipment. Measurement invalid; no results obtained.
I	Interference from localized activity in another part of the subject's body. Measurement invalid; no results obtained.
L	Location of internal or external activity was qualitatively determined by mapping, masking, or collimating. May include one or more measurement counts. These measurements are qualitative for identifying location of activity and do not yield quantifiable estimates of activity.
M	Medically administered radioactivity interfered with measurement. Measurement invalid; no results obtained.
N	No show. Worker did not meet appointment.
P	Preliminary count, when followed by a more quantitative record count. Used to indicate measurement taken, but not a record count.
R	Radon interference from subject's clothing, hair, or skin. Measurement invalid; no results obtained.
S	The subject's actions interrupted completion of the count. Measurement invalid; no results obtained.
W	Waived. Scheduled exam was waived based on needs review.
X	Measurement invalid; no results obtained. Other no-result codes do not apply. See comment field for a brief description.
Z	Test case.
Notes: 1. The comment field may have a brief explanation in addition to the codes listed above.	

Table B.15. INTERTRAC Mode-of-Intake Codes

Code	Mode of Intake
ABS	Absorption
ING	Ingestion
INH	Inhalation
NON	None (no intake)
UNK	Unknown
WND	Wound

Table B.16. INTERTRAC Evaluation Reason Codes

Code	Reason for Evaluation
A	Annual chronic intake evaluation
C	Contractor requested evaluation
H	High routine bioassay evaluation
I	Incident evaluation
N	New hire measurement or previous employment record indicated exposure prior to Hanford employment
R	Reevaluation

Table B.17. INTERTRAC Source-of-Intake Codes

Code	Source of Intake
DHE	Intake at DOE site while employed at Hanford
HAN	Intake at Hanford
NHE	Intake at non-DOE site while employed at Hanford
NOC	Nonoccupational intake
PTH	Intake occurred prior to Hanford employment

Table B.18. INTERTRAC Miscellaneous Codes

Code Type	Code	Description
Intake Confirmed	Y	Yes (occupational intake)
	N	No
Nature of Intake	A	Acute
	C	Chronic
Recorded Dose	Y	Yes (occupational intake)
	N	No
	O	Undetermined - (old evaluation assessing body burden rather than dose, or an evaluation in process)
	Z	Recorded dose is zero mrem
Source Known	Y	Yes
	N	No
Type of Evaluation	P	Preliminary
	F	Final

Table B.19. Person Codes

Code	Description
E	Employee
F	Fetus
N	Non-resident
S	Subcontractor (inactive code)
V	Visitor

Table B.20. Excreta Laboratory Codes

Code	Analytical Laboratory
IT	IT Analytical Services - Richland
LA	Los Alamos National Laboratory
OR	Oak Ridge National Laboratory
PL	PNNL Analytical Chemistry Laboratory
QN	Quanterra
RE	REECO (Reynolds Electric Company, Nevada Test Site)
ST	Severn Trent Laboratories-Richland
TA	TMA/Norcal, Richmond, California
WH	Westinghouse Hanford Company, 222-S Lab

HANFORD INTERNAL DOSIMETRY PROGRAM MANUAL
PNL-MA-552

APPENDIX C, ANALYTICAL PROCEDURES

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C.L. Antonio, Dosimetrist

Appendix C. Analytical Procedures

This appendix summarizes selected procedures that the Analytical Services Laboratory (Lab) uses to analyze indirect bioassay samples. The procedures used by the In Vivo Monitoring Program (IVMP) to perform direct bioassay measurements are also summarized here.

C.1 Indirect Bioassay Samples

All indirect bioassay samples are analyzed to determine their content of various radionuclides, according to detailed procedures written and maintained by the Lab. A brief description of most frequently used procedures follows.

C.1.1 DOELAP Category I. Beta Activity, Average Energy < 100 keV.

^{3}H — Sample distillation and subsequent liquid scintillation counting. Analytical results are calculated by a computational program proprietary to the analytical contractor.

^{14}C — Conversion of carbon to carbon dioxide and distillation. Liquid scintillation counting. Analytical results are calculated by a computational program proprietary to the analytical contractor.

Calibration — The instrument is normalized according to the procedure given in the vendor instrument manual using commercially prepared calibration and quench standards. Calibrations for specific analytes are performed annually with creation of a quench curve for efficiency correction.

C.1.2 DOELAP Category II. Beta Activity, Average Energy > 100 keV.

Sr — Wet and dry ashing, calcium phosphate precipitation, analyte separation via organic extraction, carbonate co-precipitation. Counted on gas proportional counter. If ^{90}Sr identification is desired, Y separation chemistry with ingrowth and recounting is performed. Analytical results calculated by a computational program proprietary to the analytical contractor.

Calibration — Counting efficiencies for detectors are determined by counting a NIST–traceable reference source with varying attenuation masses. The calibration curves created are verified with independently prepared sources utilizing a separate NIST-traceable sources.

C.1.3 DOELAP Category III. Alpha Activity Isotopic Analysis

Wet and dry ashing, calcium phosphate precipitation, then separation with anion exchange columns, resin extraction column used for Americium analysis. Nd(F) micro-coprecipitation, followed by alpha spectrometry counting. Analytical results calculated by a computational program proprietary to the analytical contractor. Applicable to $^{228/230}$Th, ^{232}Th, $^{234/235}$U, ^{238}U, ^{237}Np, $^{239/240}$Pu, ^{238}Pu, and ^{241}Am. Counting time is 2500 minutes for routine and priority processing, and 10,000 minutes for the low-level plutonium (IPUL) analysis.

Calibration — Detection efficiency is determined by counting a calibrated activity reference source. Sufficient counts are accumulated to make the counting uncertainty less than 1%. Energy resolution is measured with the detection efficiency, and serves primarily as a relative bench mark of detector performance. Successive measurements with the same source will reveal any significant changes in the detector's resolution. The energy calibration is performed at three different energies in the energy range of interest, between 4 and 7 Mev. A reference source containing several NIST-traceable radionuclides is used for calibration. The calculation is performed by the computer software that controls the spectrometer.

C.1.4 DOELAP Category IV. Elemental Analysis (by mass)

Uranium — Wet and dry ashing, followed by chemical separation using an anion exchange resin, then measured by kinetic phosphorescence analysis (KPA, also known as laser-induced phosphorescence analysis) using the Chemchek system.

Calibration — The KPA is calibrated daily when samples are analyzed. The calibration is performed with NIST-traceable standards and verified with standards from a different NIST-traceable source. During the analytical day, continuing calibration verifications (CCVs) are performed with each analytical batch of samples to monitor for calibration changes.

C.1.5 DOELAP Category V. Gamma (Photon) Activity Analysis

Gamma — A standard volume is directly counted on a germanium detector for urine samples. Fecal samples are wet and dry ashed, then dissolved. Canberra counting system used for nuclide identification. Analytical results calculated by a computational program proprietary to the analytical contractor.

Calibration — A calibration standard containing sufficient radionuclides to provide photopeaks spanning the entire energy region to be calibrated is counted annually. The calibration standard is purchased directly from a standards provider and maintains NIST-traceability. An efficiency curve is created using the efficiency at each photopeak energy. The efficiency is verified with a verification standard from a separate source.

C.1.6 Combinations

Usually, more than one procedure can be performed on one sample. For instance, a urine sample can be extracted for tritium analysis before any of the other analyses are begun. Some of the other more common combinations of sequential analyses are:

- plutonium and strontium
- plutonium and americium
- plutonium and uranium
- plutonium, strontium, and americium.

In special cases a single sample may be spilt for separate, non-sequential analyses.

C.2 Direct Bioassay Measurements

Details concerning procedures, equipment, and data processing for direct bioassay measurements are provided in the *In-Vivo Monitoring Program Manual*.[a] Pertinent information is provided as follows.

C.2.1 Whole Body Counts

Whole body counts are performed using the stand-up counter (a five-detector NaI system in a stand-up position within a shielded booth) or a high resolution germanium detector system involving an array of coaxial high-purity germanium (HPGe) detectors in a shielded counting room. Most radionuclides with gamma-ray energies from about 200 to 3000 keV can be quantified (e.g., ^{137}Cs, ^{60}Co). The germanium detectors have much better photopeak resolution, which generally eliminates interferences from medical radionuclides and natural radon progeny. The stand-up counter uses a 200-second count and can make some determination of spatial distribution of radioactivity as being in the head, chest, abdomen, or legs by identifying the detector with the most counts. The coaxial system uses a 600-second count time, with the option of longer counts, and can be used in either a moving scan or static position mode.

If a radionuclide other than ^{40}K is detected, the person is asked to shower, change into clean coveralls, and be recounted. The recount may be performed either on the same system as the initial measurement, or on a more sensitive system.

C.2.2 Chest Counts for Lung Activity

The presence of high-energy gamma-emitting radionuclides in the chest is determined by whole body counting or stationary counting using the coaxial germanium system. The presence in the chest of gamma- or x-ray-emitting radionuclides with energies in the range of a few tens of keV to 200 keV is determined by chest counting. The chest counter routinely reports ^{241}Am, ^{235}U, and ^{234}Th (as an indicator of ^{238}U). A peak search program is used to identify the presence of other significant photon energies.

The two chest counting systems used to detect nuclides that emit low energy photons each consist of an array of four planar HPGe detectors and associated electronics. The detectors are positioned anteriorly over the lungs in light contact with the chest. The subject is seated in a slightly reclining position. The routine counting time is 3000 seconds. Longer count times are employed where a lower detection level is required.

If a radionuclide is detected, the person is asked to shower, change into clean coveralls, and be recounted. The recount will usually be slightly longer in duration to improve sensitivity.

(a) Internal manual, PNL-MA-574, Pacific Northwest Laboratory, Richland, Washington.

If material is detected in the chest, then an ultrasound measurement of the thickness of the chest is made, and the calculated activity in the lung is corrected for the absorption of the low-energy rays in the chest wall.

Additional corrections can be performed when activity such as ^{241}Am can exist simultaneously in the lung, liver, and bone. Such correction will usually be made based on additional measurements, notably head counts and liver counts. The final corrected activity represents a best estimate of the activity actually in the lung.

C.2.3 Head Counts for Skeleton Activity

Head counts are performed to quantify the skeletal activity of low-energy x-or gamma-ray-emitting radionuclides, such as ^{241}Am. The head count consists of planar germanium detectors placed on the forehead. The typical count time is 3000 seconds. The results of the head count are converted to activity in the total skeleton based on the distribution of ^{241}Am observed in the skeleton of a total body donation to the U.S. Transuranium Registry.

C.2.4 Thyroid Counts

Thyroid measurements are routinely performed using a single HPGe detector positioned 10 cm above the thyroid. The routine counting time is 600 seconds.

C.2.5 Liver Counts

Liver measurements are performed using arrays of HPGe detectors positioned anteriorly over the liver in light contact with the subject. The routine counting time is 3000 seconds. Routine calibrations are performed for ^{241}Am. If a significant amount of activity is also present in the skeleton, then the measurement count rate over the liver is corrected for contribution from the skeleton. The liver calibration factors are determined based on the thickness of the tissue over the liver.

C.2.6 Wound Counts

Wound counts may be performed at the 747-A Building (IVRRF) or in field locations, depending on the circumstances. For low-energy x- or gamma rays, a single germanium detector is used. A portable germanium spectroscopy system is also available for making low energy wound counts. For small, localized puncture wounds, a large volume coaxial HPGe detector is usually used at IVRRF to estimate the activity for nuclides that emit high-energy photons. The typical count time is 10 minutes. The activity of plutonium isotopes should be considered approximate, unless the depth of the activity in the tissue and relative abundance of each plutonium isotope are known.

Appendix D. Sample Kit Instructions

User instructions for each of the Analytical Services Laboratory's ten sample kits are reproduced in this appendix.

Exhibit	Kit Code	Application
D.1	1	Approximate 24-hr Routine At-Home Urine Sampling (laboratory delivery and pick-up)
D.2	2	Termination Urine Sampling (laboratory delivery and pick-up)
D.3	3	24 Hour Total Urine Sampling Home Fraction (laboratory delivery and pick-up)
D.4	4	Single-Void Urine Sampling (laboratory delivery and pick-up)
D.5	5	Collecting a Fecal Sample (laboratory delivery and pick-up)
D.6	6	Special Urine Sampling (laboratory delivery and pick-up)
D.7	7	Soluble-Uranium-in-Urine Sampling (laboratory delivery and pick-up)
D.8	8	Collecting a Fecal Sampling (laboratory delivery and pick-up)
D.9	9	Collecting a Urine Sample for Mailing (laboratory delivery and pick-up)
D.10	A	Approximate 48-hr Routine At-Home Urine Sampling (laboratory pick-up and delivery)
D.11	B	12-hour urine collection for termination sample (Laboratory delivery Only)
D.12	P	Approximate 24-hr Routine At-Home Urine Sampling (laboratory pick-up only)
D.13	Q	Termination Urine Sampling (laboratory pick-up only)
D.14	R	24 Hour Total Urine Sampling Home Fraction (laboratory pick-up only)
D.15	S	Single-Void Urine Sampling (laboratory pick-up only)
D.16	T	Collecting a Fecal Sample (laboratory pick-up only)
D.17	U	Special Urine Sampling (laboratory pick-up only)
D.18	V	Soluble-Uranium-in-Urine Sampling (laboratory pick-up only)
D.19	W	Collecting a Fecal Sampling (laboratory pick-up only)
D.20	X	Collecting a Urine Sample for Mailing (laboratory pick-up only)
D.21	Y	Approximate 48-hr Routine At-Home Urine Sampling (laboratory pick-up only)

The actual instruction cards are printed on different colors of card stock for easy visual discrimination. The color is noted parenthetically in the exhibits.

See Appendix B (Table B.4) for a description of the application for each sample kit.

Exhibit D.1. Instructions for Kit Code 1: Approximate 24-hr Routine At-Home Urine Sampling.(laboratory delivery and pick-up)

(orange)

Kit Code 1

INSTRUCTIONS
FOR ROUTINE BIOASSAY AT-HOME SAMPLING

PEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify **STL, Inc., Bioassay Section,** of any errors by phoning (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M.

- Please collect **ALL** urine excreted within the periods one-half hour before retiring and one-half hour after rising for two consecutive days.

If kit was delivered on:	**Start collection on:**	**End collection morning of:**	**Kit will be picked up:**
Monday	Monday	Wednesday	Wednesday
Tuesday	Tuesday	Thursday	Thursday
Wednesday	Wednesday	Friday	Friday
Thursday	Saturday	Monday	Monday
Friday	Saturday	Monday	Monday

- Urine passed only during the specified periods should be collected.

- Keep the bottles capped when not in use.

- Three bottles are provided in the kit. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.

- After final sampling has been completed, tighten each cap, replace the bottles in the cardboard box and return the kit to the same place you received it. It will be picked up on the pickup date indicated above. If you work a shift other than the day shift and will NOT have your kit out before 8 AM on the day of sample pick-up, please call the number above to arrange for a later pick-up.

STL Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland WA 99352

Exhibit D.2. Instructions for Kit Code 2: Termination Urine Sampling (laboratory delivery and pick-up)

(goldenrod)

Kit Code 2

INSTRUCTIONS

FOR TERMINATION BIOASSAY SAMPLING

PLEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify **STL, Inc., Bioassay Section,** of any errors by phoning (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M.
- Your employer has requested a final urine specimen from you to complete your individual radiation exposure history record. This is part of your employer's termination procedure.
- Please collect **ALL** urine passed within one-half hour of retiring on the above sample date and within one-half hour of rising.
- Keep the bottles capped when not in use.
- Three bottles are provided in the kit. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.
- After final sampling has been completed, tighten each cap, replace the bottles in the cardboard box and return the kit to the same place you received it.
- The bioassay sampling kit will be picked up from he same place it was dropped off on the pickup date indicated above.

STL, Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland, Washington 99352

Exhibit D.3. Instructions for Kit Code 3: 24 Hour Total Urine Sampling, Home Fraction (laboratory delivery and pick-up)

(light yellow) Kit Code 3

INSTRUCTIONS

FOR 24 HOUR TOTAL URINE SAMPLING HOME FRACTION

PLEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify **STL, Inc., Bioassay Section,** of any errors by phoning (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M.
- Please collect **ALL** urine passed from **MIDNIGHT TO MIDNIGHT** on the sample data as shown on the kit label. This kit is provided for home collection. A second kit may be provided for your use while at work.
- Keep the bottles capped when not in use.
- Three bottles are provided in the kit. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.
- After final sampling has been completed, tighten each cap, replace the bottles in the cardboard box and return the kit to the same place you received it.
- The bioassay sampling kit will be picked up from at the same place it was dropped off on the pickup date indicated above.

STL, Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland, WA 99352

Exhibit D.4. Instructions for Kit Code 4: Single-Void Urine Sampling (laboratory delivery and pick-up)

(green)

Kit Code 4

INSTRUCTIONS

FOR SINGLE-VOID URINE SAMPLING

PLEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify **STL, Inc., Bioassay Section,** of any errors by phoning (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M.
- Unless you have been instructed otherwise, please collect a single **NORMAL** voiding of urine in one of the bottles provided.
- Cap the bottle tightly. Replace the bottle in the kit and return it to the same place you received.
- The kit will be picked up from the same place it was dropped off either today or tomorrow.

STL, Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland, WA 99352

Exhibit D.5. Instructions for Kit Code 5: Collecting a Fecal Sample (laboratory delivery and pick-up)

(light blue)

Kit Code 5

Sample Date _____

Delivery Date_____ Pickup Date_____

INSTRUCTIONS

FOR COLLECTING A FECAL SAMPLE

PLEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify **STL, Inc., Bioassay Section**, of any problems or discrepancies in the information on the label. Phone Richland (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M.
- Please collect a stool specimen (fecal sample) on the above date. If there is no voiding on the sample date, collect the next voiding and put the correct sample date on the label.
- Place the kit in the place it was delivered after sampling has been completed.
- STL will automatically schedule pickup on the date indicated above. If a sample could not be collected on the first day, please call STL, Richland at (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M. to reschedule your kit retrieval.

STL, Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland, WA 99352

ADDITIONAL INSTRUCTION ON BACK OF CARD

Directions for use:

1. Remove container, frame-holder and plastic bag from sample kit, and remove container lid.
2. Place plastic bag in container with top folded over outer edges. Insert container-bag unit in frame holder.
2. Pull up toilet seat, place unit on bowl in center toward rear of bowl.
3. Put toilet seat on frame to hold unit in place. CAUTION: Stool specimen must not contain urine.
4. After stool specimen has been collected, remove plastic bag from rim of the container and fold over the stool sample. Replace cover and return to sample box.

Exhibit D.6. Instructions for Kit Code 6: Special Urine Sampling
(laboratory delivery and pick-up)

(red)

Kit Code 6

INSTRUCTIONS
FOR SPECIAL URINE SAMPLING

PLEASE READ AND FOLLOW CAREFULLY

- Check the box for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify **STL, Inc., Bioassay Section,** of any errors by phoning (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M.

- **UNLESS YOU HAVE BEEN INSTRUCTED OTHERWISE,** please collect **ALL** urine passed starting one-half hour before retiring on the above sample date and ending one-half hour after rising.

- Keep the bottles capped when not in use.

- Three bottles are provided in the kit. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.

- After final sampling has been completed, tighten each cap, replace the bottles in the cardboard box and return the kit to the same place you received it.

- The bioassay sampling kit will be picked up from the same place it was dropped off on the pickup date indicated above.

STL, Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland, WA 99352

Exhibit D.7. Instructions for Kit Code 7: Soluble-Uranium-in-Urine Sampling (laboratory delivery and pick-up)

(chartreuse)

Kit Code 7

INSTRUCTIONS
FOR SOLUBLE URANIUM IN URINE SAMPLING

PLEASE READ AND FOLLOW CAREFULLY

Routine collection and analysis of urine samples is an important part of the radiation dosimetry program for individuals working with soluble uranium. Therefore, it is requested that you read and carefully follow the instructions below.

- Check the kit for your correct, name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify **STL, Inc., Bioassay Section**, of any errors by phoning (509) 375-3131, collect, between 8:00 A.M. and 4:30 A.M.

- Please collect ALL urine excreted within one-half hour before retiring on Sunday evening and one-half hour after rising on Monday morning.

- Keep the bottles capped when not in use.

- Three bottles are provided in the kit. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.

- After final sampling has been completed, please place all bottles, whether used or not, into the cardboard carrier and refold the handle to close the box.

- Your kit will be picked up on **Monday** morning from the same place where it was delivered. Be sure to leave your kit where it was delivered so it can be picked up.

STL, Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland, WA 99352

Exhibit D.8. Instructions for Kit Code 8: Collecting a Fecal Sample (laboratory delivery and pick-up)

(grey blue)

Kit Code 8

INSTRUCTIONS

FOR COLLECTING A FECAL SAMPLE

IMPORTANT: IF POSSIBLE, DO NOT USE UNTIL 24 HOURS AFTER LEAVING WORK PLACE.

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify **STL, Inc., Bioassay Section,** of any problems or discrepancies in the information on the container. Phone Richland (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M.
- Please collect a stool specimen (fecal sample) on the above date. If there is no voiding on the sample date, collect the next voiding and put the correct sample date on the label.
- Place the kit in the place it was delivered after final sampling has been completed.
- STL will automatically schedule pickup on the date indicated above. If a sample could not be collected on the first day, please call STL, Richland at (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M. to reschedule your kit retrieval.

CHECK TIME OUT OF ZONE:

O Less than 1 day

O 1-3 days

O More than 3 days

ADDITIONAL INSTRUCTIONS ON BACK OF CARD

Directions for use:

1. Remove container frame holder and plastic bag from sample kit, and remove container lid.
2. Place plastic bag in container with top folded over outer edges. Insert container-bag unit in frame holder.
2. Pull up toilet seat, place unit on bowl in center toward rear of bowl.
3. Put toilet seat on frame to hold unit in place. CAUTION: Stool specimen must not contain urine.
4. After stool specimen has been collected, remove plastic bag from rim of the container and fold over the stool sample. Replace cover and return to sample box.

Exhibit D.9. Instructions for Kit Code 9: Collecting a Urine Sample for Mailing (laboratory delivery and pick-up)

(pink)

Kit Code 9

INSTRUCTIONS
FOR COLLECTING A URINE SAMPLE FOR MAILING

PLEASE READ AND FOLLOW CAREFULLY

1. Discard the outer box. Write the start date here: _____

2. Please collect ALL urine while at home until all bottles are used.

3. Three bottles are provided in the kit. Begin with any bottle and fill each bottle at least to the fill line but no higher than the bottle neck.

4. Keep the bottles capped when not in use.

5. After final sampling has been completed, recheck each cap for tightness. Replace the bottles in the cardboard box with the instruction card. Seal the box by moistening the gummed surface of the tape provided and centering over the box closure.

6. Return the package to STL, Inc.

7. If you have any questions, please call STL, Inc., Bioassay Section, at (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M.

STL, Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland, WA 99352

Exhibit D.10. Instructions for Kit Code A: Approximate 48-hr Routine At-Home Urine Sampling (laboratory delivery and pick-up)

Kit Code A

INSTRUCTIONS
FOR ROUTINE BIOASSAY AT-HOME SAMPLING

PEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify **STL, Inc., Bioassay Section,** of any errors by phoning (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M.

- Please collect **ALL** urine excreted within the periods one-half hour before retiring and one-half hour after rising for four consecutive days.

If kit was delivered on:	**Start collection on:**	**End collection morning of:**	**Kit will be picked up:**
Monday	Monday	Friday	Friday
Tuesday	Thursday	Monday	Monday
Wednesday	Thursday	Monday	Monday
Thursday	Thursday	Monday	Monday
Friday	Friday	Tuesday	Tuesday

- Urine passed only during the specified periods should be collected.

- Keep the bottles capped when not in use.

- Each kit consists of **TWO** boxes. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.

- After final sampling has been completed, tighten each cap, replace the bottles in the cardboard boxes and return the kit to the same place you received it. It will be picked up on the pickup date indicated above.

STL, Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland WA 99352

Exhibit D.11. Instructions for Kit Code B: 12-hour urine collection for termination sample (Laboratory Delivery Only)

Kit Code B

INSTRUCTIONS

FOR TERMINATION BIOASSAY SAMPLING

PLEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify **STL, Inc., Bioassay Section,** of any errors by phoning (509) 375-3131, collect (if necessary), between 8:00 A.M. and 4:30 P.M.
- Your employer has requested a final urine specimen from you to complete your individual radiation exposure history record. This is part of your employer's termination procedure.
- Please collect **ALL** urine passed within one-half hour of retiring on the above sample date and within one-half hour of rising the next morning.
- Keep the bottles capped when not in use.
- Three bottles are provided in the kit. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.
- After final sampling has been completed, tighten each cap, replace the bottles in the cardboard box and return the kit to one of the locations specified in the SPECIAL TERMINATION BIOASSAY INSTRUCTIONS provided by your employer. DO NOT LEAVE THE KIT AT YOUR RESIDENCE.

STL, Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland, Washington 99352

Exhibit D.12. Instructions for Kit Code P: Approximate 24-hr Routine At-Home Urine Sampling. (Laboratory pick-up only)

(orange)

Kit Code P

INSTRUCTIONS
FOR ROUTINE BIOASSAY AT-HOME SAMPLING

PEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify by telephone **the office issuing the kit,** of any errors.

- Please collect **ALL** urine excreted within the periods one-half hour before retiring and one-half hour after rising for two consecutive days.

If kit was received on:	**Start collection on:**	**End collection morning of:**	**Kit will be picked up:**
Monday	Monday	Wednesday	Wednesday
Tuesday	Tuesday	Thursday	Thursday
Wednesday	Wednesday	Friday	Friday
Thursday	Saturday	Monday	Monday
Friday	Saturday	Monday	Monday

- Urine passed only during the specified periods should be collected.

- Keep the bottles capped when not in use.

- Three bottles are provided in the kit. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.

- After final sampling has been completed, tighten each cap, place the kit outside near the front door. It will be picked up on the pickup date indicated above. If you work a shift other than the day shift and will NOT have your kit out before 8 AM on the day of sample pick-up, please call the number below to arrange for a later pick-up.

STL Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland WA 99352
Telephone: (509) 375-3131 ext.135

Exhibit D.13. Instructions for Kit Code Q: Termination Urine Sampling (Laboratory pick-up only)

Kit Code Q

INSTRUCTIONS

FOR TERMINATION BIOASSAY SAMPLING

PLEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify by telephone **the office issuing the kit** of any errors.

- Your employer has requested a final urine specimen from you to complete your individual radiation exposure history record. This is part of your employer's termination procedure.

- Please collect **ALL** urine passed within one-half hour of retiring on the above sample date and within one-half hour of rising the next morning.

- Keep the bottles capped when not in use.

- Three bottles are provided in the kit. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.

- After final sampling has been completed, tighten each cap, replace the bottles in the cardboard box and place the kit outside near the front door. If you will NOT have your kit out before 8 AM on the day of sample pick-up, please call the number below to arrange for a later pick-up.

STL Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland WA 99352
Telephone: (509) 375-3131 ext.135

Exhibit D.14. Instructions for Kit Code R: 24 Hour Total Urine Sampling, Home Fraction (Laboratory pick-up only)

Kit Code R

(Light Yellow)

FOR 24 HOUR TOTAL URINE SAMPLING
HOME FRACTION

PLEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify by telephone **the office issuing the kit** of any errors.

- Please collect **ALL** urine passed from **MIDNIGHT TO MIDNIGHT** on the sample data as shown on the kit label. This kit is provided for home collection. A second kit may be provided for your use while at work.

- Keep the bottles capped when not in use.

- Three bottles are provided in the kit. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.

- After final sampling has been completed, tighten each cap, replace the bottles in the cardboard box and place the kit outside near the front door.

- The bioassay sampling kit will be picked up from at the same place it was dropped off on the pickup date indicated above. If you will NOT have your kit out before 8 AM on the day of sample pick-up, please call the number below to arrange for a later pick-up.

STL Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland WA 99352
Telephone: (509) 375-3131 ext.135

Exhibit D.15. Instructions for Kit Code S: Single-Void Urine Sampling
(Laboratory pick-up only)

Kit Code S

INSTRUCTIONS

FOR SINGLE-VOID URINE SAMPLING

PLEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify by telephone **the office issuing the kit** of any errors.

- Unless you have been instructed otherwise, please collect a single **NORMAL** voiding of urine in one of the bottles provided.

- Cap the bottle tightly. Replace the bottle in the kit and place the kit outside near the front door.

- The kit will be picked up from your residence either today or tomorrow. If you will NOT have your kit out before 8 AM on the day of sample pick-up, please call the number below to arrange for a later pick-up.

STL Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland WA 99352
Telephone: (509) 375-3131 ext.135

Exhibit D.16. Instructions for Kit Code T: Collecting a Fecal Sample (Laboratory pick-up only)

Kit Code T

Sample Date _____

Delivery Date_____ Pickup Date_____

INSTRUCTIONS

FOR COLLECTING A FECAL SAMPLE

PLEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify by telephone **the office issuing the kit** of any errors.
- Please collect a stool specimen (fecal sample) on the above date. If there is no voiding on the sample date, collect the next voiding and put the correct sample date on the label.
- Place the kit outside near the front door after sampling has been completed.
- STL will automatically schedule pickup on the date indicated above. If a sample could not be collected on the first day, please call STL, Richland at (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M. to reschedule your kit retrieval.

STL, Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland, WA 99352

ADDITIONAL INSTRUCTION ON BACK OF CARD

Exhibit D.16. (contd)

ADDITIONAL INSTRUCTION ON BACK OF CARD

Directions for use:

1. Remove container, frame-holder and plastic bag from sample kit, and remove container lid.
2. Place plastic bag in container with top folded over outer edges. Insert container-bag unit in frame holder.
3. Pull up toilet seat, place unit on bowl in center toward rear of bowl.
4. Put toilet seat on frame to hold unit in place. CAUTION: Stool specimen must not contain urine.
5. After stool specimen has been collected, remove plastic bag from rim of the container and fold over the stool sample. Replace cover and return to sample box.

Exhibit D.17. Instructions for Kit Code U: Special Urine Sampling
(Laboratory pick-up only)

(red)

Kit Code U

INSTRUCTIONS
FOR SPECIAL URINE SAMPLING

PLEASE READ AND FOLLOW CAREFULLY

- Check the box for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify by telephone **the office issuing the kit** of any errors.

- **UNLESS YOU HAVE BEEN INSTRUCTED OTHERWISE,** please collect **ALL** urine passed starting one-half hour before retiring on the above sample date and ending one-half hour after rising.

- Keep the bottles capped when not in use.

- Three bottles are provided in the kit. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.

- After final sampling has been completed, tighten each cap, replace the bottles in the cardboard box and place the kit outside near the front door.

- The bioassay sampling kit will be picked up from your residence on the pickup date indicated above. If you will NOT have your kit out before 8 AM on the day of sample pick-up, please call the number below to arrange for a later pick-up.

STL Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland WA 99352
Telephone: (509) 375-3131 ext.135

Exhibit D.18. Instructions for Kit Code V: Soluble-Uranium-in-Urine Sampling (Laboratory pick-up only)

Kit Code V

INSTRUCTIONS
FOR SOLUBLE URANIUM
IN URINE SAMPLING

PLEASE READ AND FOLLOW CAREFULLY

Routine collection and analysis of urine samples is an important part of the radiation dosimetry program for individuals working with soluble uranium. Therefore, it is requested that you read and carefully follow the instructions below.

- Check the kit for your correct, name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify by telephone **the office issuing the kit** of any errors.
- Please collect ALL urine excreted within one-half hour before retiring on Sunday evening and one-half hour after rising on Monday morning.
- Keep the bottles capped when not in use.
- Three bottles are provided in the kit. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.
- After final sampling has been completed, please place all bottles, whether used or not, into the cardboard carrier and refold the handle to close the box.
- Your kit will be picked up on **Monday** morning. Be sure to leave your kit outside your residence so it can be picked up. If you will NOT have your kit out before 8 AM on the day of sample pick-up, please call the number below to arrange for a later pick-up.

STL Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland WA 99352
Telephone: (509) 375-3131 ext.135

Exhibit D.19. Instructions for Kit Code W: Collecting a Fecal Sample (Laboratory pick-up only)

Kit Code W

INSTRUCTIONS

FOR COLLECTING A FECAL SAMPLE

IMPORTANT: IF POSSIBLE, DO NOT USE UNTIL 24 HOURS AFTER LEAVING WORK PLACE.

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. . Please notify by telephone **the office issuing the kit** of any errors.
- Please collect a stool specimen (fecal sample) on the above date. If there is no voiding on the sample date, collect the next voiding and put the correct sample date on the label.
- Place the kit outside near the front door after final sampling has been completed.
- STL will automatically schedule pickup. If a sample could not be collected on the first day, please call STL, Richland at (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M. to reschedule your kit retrieval.

CHECK TIME OUT OF ZONE:

O Less than 1 day

O 1-3 days

O More than 3 days

ADDITIONAL INSTRUCTIONS ON BACK OF CARD

Directions for use:

1. Remove container, frame holder and plastic bag from sample kit, and remove container lid.
2. Place plastic bag in container with top folded over outer edges. Insert container-bag unit in frame holder.
2. Pull up toilet seat, place unit on bowl in center toward rear of bowl.
3. Put toilet seat on frame to hold unit in place. CAUTION: Stool specimen must not contain urine.
4. After stool specimen has been collected, remove plastic bag from rim of the container and fold over the stool sample. Replace cover and return to sample box

Exhibit D.20. Instructions for Kit Code X: Collecting a Urine Sample for Mailing (Laboratory pick-up only)

(pink)

Kit Code X

INSTRUCTIONS
FOR COLLECTING A URINE SAMPLE FOR MAILING

PLEASE READ AND FOLLOW CAREFULLY

1. Write the start date here: _____

2. Please collect ALL urine while at home until all bottles are used.

3. Three bottles are provided in the kit. Begin with any bottle and fill each bottle at least to the fill line but no higher than the bottle neck.

4. Keep the bottles capped when not in use.

5. After final sampling has been completed, recheck each cap for tightness. Replace the bottles in the cardboard box with the instruction card. Seal the box by moistening the gummed surface of the tape provided and centering over the box closure.

6. Return the package to STL, Inc.

7. If you have any questions, please call STL, Inc., Bioassay Section, at (509) 375-3131, collect, between 8:00 A.M. and 4:30 P.M.

STL, Inc.
BIOASSAY SECTION
2800 George Washington Way

Exhibit D.21. Instructions for Kit Code Y: Approximate 48-hr Routine At-Home Urine Sampling (Laboratory pick-up only)

Kit Code Y

INSTRUCTIONS
FOR ROUTINE BIOASSAY AT-HOME SAMPLING

PEASE READ AND FOLLOW CAREFULLY

- Check the kit for your correct name, address, and payroll number **BEFORE** collecting a sample. **DO NOT USE** this kit if it is not addressed to you. Please notify by telephone **the office issuing the kit** of any errors.

- Please collect **ALL** urine excreted within the periods one-half hour before retiring and one-half hour after rising for four consecutive days.

If kit was delivered on:	**Start collection on:**	**End collection morning of:**	**Kit will be picked up:**
Monday	Monday	Friday	Friday
Tuesday	Thursday	Monday	Monday
Wednesday	Thursday	Monday	Monday
Thursday	Thursday	Monday	Monday
Friday	Friday	Tuesday	Tuesday

- Urine passed only during the specified periods should be collected.

- Keep the bottles capped when not in use.

- Each kit consists of **TWO** boxes. Begin with any bottle and use as many as necessary. Each bottle may be filled until approximately 3/4 full.

- After final sampling has been completed, tighten each cap, replace the bottles in the cardboard boxes and leave outside your residence. It will be picked up on the pickup date indicated above. If you will NOT have your kit out before 8 AM on the day of sample pick-up, please call the number below to arrange for a later pick-up.

STL Inc.
BIOASSAY SECTION
2800 George Washington Way
Richland WA 99352
Telephone: (509) 375-3131 ext.135

Appendix E. Example Potential Intake Responses

This appendix describes some example responses to potential intakes. It focuses on bioassay measurements, their capability and application to the dose assessment process, and action levels for consideration of dose reduction therapy. It is not intended that these examples be considered comprehensive or absolute. They are provided as examples of the kind and quality of dose estimates that can be made based on data available at various times following an intake. The exposure evaluator is responsible for interpreting the data available and estimating dose for actual cases, based on the unique aspects and data obtained for that case. Likewise, the discussion of dose reduction therapy is provided for general information. The HEHF Occupational Medicine staff are the Hanford Site authorities responsible for dose reduction therapeutic measures.

E.1 Example Incident Bioassay Responses

The IDP has a wide range of bioassay measurements and processing categories available. Following an incident of potential intake, the exposure evaluator recommends an investigation bioassay protocol to the contractor dosimetry representative. Factors considered in this recommendation include the type of intake, radionuclides involved, probable severity of intake, information needs of the physician and the worker's management, and the relative cost-effectiveness of reasonable alternatives. There is a trade-off between the promptness by which estimates of intake or dose can be made and the accuracy of those estimates. Some example responses for the most probable radionuclides and scenarios at Hanford follow. The discussion also provides estimates of minimum detectable dose (in terms of the resulting CEDE) that can be determined at various stages of response.

E.1.1 Tritium Intake Assessment

Single-void or overnight urine sampling is the recommended bioassay method for an unplanned intake of tritium. A single-void sample obtained 2 or more hours after the intake can be adequate for dosimetry. Generally, an overnight sample or next-morning single-void sample provides adequate response for dosimetry. Dose assessment can be made based on either of these two samples, with a minimum detectable dose of about 1 mrem. However, if the dose estimated at that time is greater than 100-mrem CEDE, then additional samples collected over the next 2 weeks should be obtained to improve the precision of the dose assessment.

It is unlikely that an intake of tritium could occur at Hanford that would require emergency processing of urine samples for purposes of treatment, but emergency processing might be important for reporting purposes. Priority processing (3-day analysis time) is usually adequate. This decision can best be made at the time the sample is collected.

E.1.2 Mixed Fission and Activation Product Intake Assessment

Mixed fission and activation products emitting gamma-rays with energies >300 keV are easily measured by whole body counting. A whole body, wound, or thyroid count (if radioiodine is suspected) within the first week after intake is sufficiently sensitive to confirm an intake resulting in a few mrem CEDE. Counts taken on the same day as the intake should generally not be used for dose assessment because of the possible interference from external contamination and because of the rapidly changing biokinetics of the material. If a same-day count results in an estimated dose >10-mrem CEDE, then an additional count should be obtained during the next 7 days. If the estimated dose is >100 mrem, several more counts should be obtained over a period approximately the same as the effective retention half-time in the body (or 6 months, whichever is shorter) to quantify the dose.

Excluding special research projects, the only high-energy gamma emitting nuclides likely to be of concern now at the Hanford site are ^{137}Cs, ^{60}Co, and $^{154/155}Eu$. Other mixed fission or activation products have either decayed away or are mixed with and produce much less dose than the four principal radionuclides. If ^{137}Cs is detected, consideration should be given to other nuclides potentially involved and the appropriateness of excreta bioassay.

E.1.3 Strontium-90 Intake Assessment

There are some places onsite where workers may be exposed to ^{90}Sr without accompanying ^{137}Cs or other gamma-emitting radionuclides. Generally, a 12-hour urine sample analyzed by expedite processing is sufficient to give a prompt indication of the severity of the intake down to a few mrem. Actual dose assessment should be based on at least one 24-hour (or approximate 24-hour) urine sample taken a few days after the intake and analyzed by priority processing. If the preliminary dose estimate is >100 mrem, then several urine samples should be obtained during the next couple of months.

If workplace monitoring indicates a potential for a very large intake, then same-day and next-day in vivo counts should be made and a second-void urine sample should be obtained and analyzed by emergency processing. In vivo bremsstrahlung counting should be able to detect an intake down to 1-rem CEDE within a few hours after intake, and the urine sample should be able to detect an intake around 10-mrem CEDE within 12 to 24 hours after intake. Therefore, a decision to begin or end treatment can easily be made within a few hours after intake.

E.1.4 Uranium Intake Assessment, Soluble Forms

Because most uranium at Hanford is natural, depleted, or just slightly enriched (up to 1.2% ^{235}U), soluble forms of uranium (e.g., UO_3 and uranyl nitrate) can pose a chemical as opposed to a radiological hazard. If a major intake is suspected, early response is focussed on the kidney burden relative to the threshold for transient toxicity. A same-day chest count should be made as quickly as possible, and a second-void urine sample should be obtained and analyzed by emergency processing. The second-void urine sample should be followed by an overnight or 12-hour sample. Twenty-four-hour samples would follow if the worker is being treated. The chest count

should be able to detect an intake of about 45 -90 mg (Class D and W) depending on how soon after intake the measurement is made, and the spot urine sample should be able to detect an intake of about 1 - 5 mg Class D and W. If anything is detected in a chest count, or if the spot urine and 12-hour urine samples exceed 0.1 mg or 0.3 mg, respectively, then HEHF should be notified. Monitoring of kidney function is recommended.

If workplace monitoring or prompt urine results indicate that the threshold for toxicity was not approached, then actual dose assessment should be based on at least one 24-hour (or approximate 24-hour) urine sample taken at least 3 days after the intake and analyzed by priority processing. The 3-day delay allows for elimination from the body of the unabsorbed fraction of the intake, which can introduce a large error in the dose calculation. Doses down to fractions of a mrem can be detected at that time.

E.1.5 Uranium Intake Assessment, Insoluble Forms

Uranium that is more slowly transferred from the lung or wound site can be encountered at the former fuel production or metallurgy facilities (e.g., 303-M, 333, and 306-W Buildings) and may possibly be contained in liquid effluent pipes or disposal sites associated with such facilities.

An inhalation of class Y uranium is considered the most difficult to detect. Details of the response capabilities are given in Table E.1. Early fecal samples are essential for good estimates of class Y intakes. The presence of a small class D component can improve the early urine sampling sensitivity but also if dose calculations are based on urine samples alone, a small uncertainty in the percentage of class D material present in an intake could lead to a large miscalculation of the dose.

If activity in urine remains above normal after the first couple of days, then additional urine samples should be obtained at about 5, 10 and 30 days after intake.

Table E.1. Inhalation of Recycled Class Y Uranium, No Treatment

Days Post-intake	Measurements	When Results Are Known	What Can Be Said At That Point	Problems or Comments
Same day	3000-s chest count	Same day	Can say if CEDE is < or > 5 rem	If ^{235}U or ^{234}Th detected, advise HEHF for treatment decision.
Same day	2nd voiding spot urine emergency processing	Same day or first thing next Monday	Can say if CEDE is < or> 1rem	If spot urine > 60 μg, advise HEHF for possible treatment
1	If chest count detects activity, then collect a 12-h urine, emergency processing, and a second chest count.	End of second day	No real change in detectable dose, but second chest count will help determine split between class D and class Y, and 12-h urine will improve accuracy of dose estimate and efficacy of treatment.	
1	If first chest count did not detect activity, then collect 24-h total urine and expedite processing.	Morning of the fifth day	If nothing in sample, then dose ismost likely <20 mrem.	If nothing in 24-h sample, collect at least one more and analyze priority processing.
1-3	Two fecal samples; priority processing.	12 to 14 days after intake	Capable of determining <5 mrem	Used to determine class Y component of intake

If there is only normal activity in urine but the activity is >100 times the minimum detectable amount (MDA) in feces, then as a minimum an additional fecal sample should be obtained at about 20 days after intake. Two samples, at 10 and at 20 to 30 days, are preferred.

Fecal samples are not required for intakes of insoluble uranium by wounds because there is no transfer of systemic uranium to the gastrointestinal tract. However, for a very significant intake of uranium via a wound, a fecal sample is suggested to verify this assumption.

Because of the lower specific activity of uranium relative to plutonium, workplace monitoring is a more reliable indicator of the severity of a uranium intake. For instance, the class Y intake resulting in a 500-mrem CEDE is about 10 mg, which should be readily detectable in the workplace. Consequently, the bioassay protocol is less automatic than for plutonium and can be tailored to reflect the seriousness of the intake as indicated by workplace monitoring. The decision to perform emergency processing of a spot urine sample on one extreme versus priority processing of a 24-hour sample on the other, or collection of a fecal sample for maximum sensitivity to inhalation intake detection is made based on the circumstances surrounding the intake.

E.1.6 Plutonium Intake Assessment

Plutonium at Hanford tends to be a mixture characterized by its weight percentage of ^{240}Pu and the time elapsed since its chemical separation and purification. The time since the plutonium was purified varies from a few years to many years, but generally there has been ample time for ^{241}Am to grow into the mixture from ^{241}Pu decay. For purposes of this discussion, a 20-year aged 6% ^{240}Pu mixture is assumed. The incident responses for various ages or types of Pu are not significantly different, however, the bioassay capabilities can vary substantially for the same response.

Details of the bioassay options and minimum detectable doses at various stages after an inhalation intake are provided in Tables E.2 and E.3. The response capabilities consider both inhalation classes W and Y. Evidence exists to suggest that class W plutonium becomes more and more like class Y as it ages, i.e., as it oxidizes at normal room temperature and humidity.

Generally, for low-level exposures (i.e., anticipated CEDE of less than 100 mrem), the bioassay protocol consists of fecal and urine sampling within the first 5 days following the intake. For super-class Y material or exposure levels greater than 100 mrem, the bioassay protocol may consist of a same-day chest count, a second-voiding urine sample, and one or more of the following:

- a 12-hour urine sample collected after the second voiding
- a 24-hour urine sample collected immediately after the 12-hour sample
- all of the fecal excretion for the first 3 to 5 days after the incident.

The fecal samples are essential if sensitivity at a 100-mrem CEDE is to be obtained for plutonium. If activity has been detected in urine during the early sampling listed in Tables E.2 and E.3, then additional urine samples should be obtained at about 5, 10, and 30 days after intake. If there has been no activity in urine but activity was >100 times the MDA in feces, then as a minimum an additional fecal sample should be obtained at about 20 days after intake. Two samples are preferred, at 10 days and at 20 to 30 days. Additional fecal samples at longer times post intake may be appropriate for verifying the excretion rate.

Details of the bioassay capability for a plutonium-contaminated wound are provided in Table E.4. Basically, the protocol consists of same-day wound counts and at least one urine sample. The decision on the type of urine sample (e.g., spot or 12-hour) and processing time will depend not only on what the wound count indicates but also on other contamination data (e.g., the results of the blood sample or the level of contamination on the wound source or on skin around the wound). A fecal sample is desirable for large intakes to verify the pathway, but is not essential.

Table E.2. Bioassay Capabilities for an Inhalation Intake of 20-year Aged 6% Pu Mixture, 5 μm AMAD Particle Size, No DTPA Given At Worksite

Days Post-Intake	Measurements	When Results Are Known	What Can Be Said At What Point	Problems Or Comments
Same day	3000-s chest count; second voiding spot urine; emergency processing	Same day or first thing next morning	Can say if CEDE is < or > 5 rem Urine can say if < or > 5 rem Class W	If anything detected, should consider DTPA.
1	12-h urine, emergency processing; second chest count if first result detected activity	End of second day	If nothing in urine or chest, then intake is class W <1 rem, class Y <5 rem	If nothing in urine, then DTPA is not needed. If Pu alpha in urine >2 dpm, then consider initiating DTPA.
2	24-h total urine, expedite processing	Morning of fifth day	If nothing in sample (and previous chest counts), then CEDE <500 mrem,	From bioassay data, still will not know inhalation class of material
1-3	Fecal excretion for first 3 days after intake Two processings by lab: 1) LEPD expedited processing, 2) IPA priority processing	LEPD results: 6-7 days after intake IPA priority: 16-17 days after intake	If nothing in LEPD analysis, then CEDE <500 mrem If nothing in IPA, then CEDE <100 mrem	

For wounds, the issue is not so much the sensitivity of early bioassay measurements, especially for shallow wounds, but the time involved to determine the biological behavior of the material. For instance, it may take months to determine the transfer rate of plutonium from the wound to blood and the quantity of plutonium transferred to the lymph system instead of to blood. Prolonged DTPA treatment will also prolong the time until the CEDE can be quantified.

Table E.3. Bioassay Capabilities for an Inhalation Intake of 20-year Aged 6% Pu Mixture, 5 μm AMAD Particle Size with DTPA Promptly Administered Based on Workplace Data

Days Post-Intake	Measurements	When Results Are Known	What Can Be Said At What Point	Problems Or Comments
Same day	3000-s chest count; second voiding spot urine, emergency processing.	Same day or first thing next morning	If CEDE is < or >5 rem. Much lower dose if sure material is class W.	Consider second DTPA shot if anything detected in spot urine.
1	12-h urine, emergency processing; second chest count if 1st detected activity.	End of second day	If nothing in urine or chest, then intake is class W<2 rem, class Y <10 rem.	If nothing in urine or chest, then DTPA can be discontinued. If Pu alpha in urine is >2 dpm, then consider continuing DTPA.
2	24-h total urine, expedite processing.	Morning of 5th day.	If nothing in sample (and previous chest counts), then CEDE class W <200 rem, class Y <4 rem.	From bioassay data, still will not know inhalation class of material.
1-3	Total fecal excretion for first 3 days post intake. Two lab processings: 1) LEPD expedited, 2) IPA priority processing (or routine processing if cost is a factor).	LEPD results: 6-7 days after intake; IPA priority: 17-18 days after intake; IPA routine: about 6 weeks after intake	If nothing in LEPD analysis, then CEDE <500 mrem. If nothing in IPA, then CEDE <100 mrem.	

The dose estimates in the tables assume that ^{241}Am has had about 20 years to build into the mixture. Longer ingrowth times will provide slight improvement for the chest count and low-energy photon (LEPD) fecal detection capabilities. However, shorter in-growth times can significantly reduce the sensitivity of chest and LEPD fecal counting. Intakes of freshly separated plutonium or pure isotopes of plutonium, are especially difficult to detect via bioassay.

Table E.4. Wound Contamination by 20-year Aged, 6% Pu Mixture, No DTPA Given at Worksite

Days Post-Intake	Measurements	When Results Are Known	What Can Be Said At What Point	Problems Or Comments
Same day	One or more wound counts; second voiding spot urine; emergency processing.	Same day or first thing next morning	Can say if CEDE is < or >3 rem.	If anything detected in wound or urine, should consider DTPA. If activity in wound is >0.5 nCi, excision should be considered.
1	12-h urine, emergency processing; second wound count if first detected activity	End of second day	Minimum detectable dose somewhat <3 rem, but cannot say exactly due to uncertainty in transfer rate from wound.	If nothing in urine or wound, then DTPA is not indicated. If Pu alpha in urine >2 dpm, then consider initiating DTPA.
2	If nothing was detected in previous samples, then one additional urine sample (24-h-simulated) is collected; priority processing.	11 days	If nothing in sample, then CEDE <100 mrem	
2	If activity was detected in previous samples, then additional wound, urine, and possibly fecal samples will be needed. Processing will depend on the activity in the samples.			

E.2 Guides for Immediate Care

E.2.1 Action Levels

Two kinds of action levels are described in this section. Notification levels are used to advise that an intake may have occurred. Intervention levels are used to assist with the decision to use medical therapy for dose reduction.

Notification levels based on workplace indicators for reacting to a potential intake are provided in Section 7 (Table 7.1) of this manual. The intent of these notification levels is to provide guidance for field response to any potential intake of radioactive material with a potential for a dose commitment that is >100-mrem CEDE. Table 7.2 provides notification levels for possible early medical intervention for intakes. These tables are based on general considerations and significant experience with past intakes of radioactive material. They do not correspond with any specifically calculated value for intake or dose commitment to the worker.

Intervention levels are developed in this appendix to assist in the medical decision to treat an intake. These action levels, based on early bioassay results, have a strong correlation with the dose commitment received by the worker for different intake situations, although the degree of uncertainty is high - especially in early bioassay sample results.

The decision to administer dose reduction therapy and the treatment protocol used are the responsibility of the physician in charge. Guidelines for the medical intervention of a radionuclide intake can be found in several publications. NCRP Report No. 65 (NCRP 1980) and the joint publication of the Commission on European Communities (CEC) and the DOE *Guidebook for the Treatment of Accidental Internal Radionuclide Contamination of Workers* (Bhattachaaryya, et al 1992) both contain detailed guidance in intervention and medical procedures useful in mitigating radiation overexposures. The CEC/DOE Guidebook expressed its guidance in terms of the annual limit on intake (ALI) levels, rather than on dose. In doing so, it used the 2-rem (20-mSv) effective dose concept of ALI, found ICRP Publication 60 (1991a) and in ICRP Publication 61 (1991b). The basic guidance can be summarized as follows:

- When the estimated intake is below one ALI, treatment should not be considered.
- When the estimated intake is between 1 and 10 times the ALI, treatment should be considered. Under these situations, short-term administration will usually be appropriate, except for intake of materials poorly transported from the lung (class Y).
- When the estimated intake exceeds 10 times the ALI, then extended or protracted treatment should be implemented, except for materials poorly transported from the lung.
- For poorly transported material in the lung, lung lavage is the only recommended treatment, and should only be considered for intakes exceeding 100 times the ALI.

Because the dose associated with the ALI in the CEC/DOE Guidebook is 2 rem CEDE and because the upper administrative level used by DOEis also 2 rem CEDE, the Hanford Site uses 2 rem and 20 rem as intervention level guidance in the manner presented in the CEC/DOE Guidebook:

- When the estimated intake is below 2-rem CEDE, treatment is not generally recommended.
- When the estimated intake is between 2-rem and 20-rem CEDE, treatment should be considered. Under these situations, short-term administration will usually be appropriate.
- When the estimated intake exceeds 20-rem CEDE, then extended or protracted treatment is strongly recommended, except for poorly transported material in the lung.

General guidelines for when treatment may be considered reasonable, based on specific bioassay results, are presented below for radionuclides common at Hanford (see Table E.5). Except for plutonium and insoluble uranium, they have been derived from internal dosimetry models of intakes that result in a CEDE of 2 rem and 20 rem, corresponding to the intervention-level guidance discussed above.

E.2.2 Tritium Intervention Levels

Tritium cannot be measured by in vivo bioassay because it emits only a low-energy beta. The most sensitive method for bioassay measurement is the amount of tritium in urine, used to estimate the total tritium in body water.

Treatment (2 rem and 20 rem)

If the results of either a single-void urine sample taken 3 to 4 hours after exposure (to ensure equilibrium of tritium in body water) or a following overnight sample exceeds 10^6 dpm/mL, HEHF should be notified (implying an intake resulting in a CEDE of about 2 rem). If the urine content exceeds 10^7 dpm/mL, treatment is strongly indicated (implying an untreated CEDE of 10 to 20 rem).

Table E.5. General Guidelines for When Treatment May be Considered Reasonable for Radionuclides Common at Hanford

Isotope	Measurement	Result	Action	Possible Treatment
Tritium				
2 rem	Single-void urine 3-4 h after exposure	10^6 dpm/mL	Notify HEHF	Fluids, diuretics
20 rem	Same	10^7 dpm/mL	Strongly recommend treatment	Fluids, diuretics
Mixed Fission Products				
2 rem (assumes 2:1 Sr/Cs ratio)	Whole body count, or urine/fecal for severe intakes	>2000 nCi uptake, or >40,000 nCi if no Sr present	Notify HEHF	Prussian blue Ca,(Sr), ammonium phosphate, others
20 rem (assumes 2:1 Sr/Cs ratio	Same	>20,000 nCi uptake, or >400,000 nCi if no Sr present	Treatment strongly recommended	Same
^{90}Sr				
2 rem	Second-void spot urine or in vivo detection	>70,000 dpm in spot urine, or >MDA in vivo	Notify HEHF	Alginate, Ca gluconate, Sr lactate, others
20 rem	Same	>700,000 dpm in spot urine, or >50 µCi in vivo	Treatment strongly recommended	Same
Uranium, Soluble				
Potential kidney toxicity	Chest count Second-void urine sample 12-hour urine sample	>MDA for ^{234}Th >0.1 mg >0.3 mg	Notify HEHF	Na or Ca bicarbonate; intestinal adsorbents
Uranium Insoluble[a]				
2 rem	Chest count	>MDA for ^{235}U or ^{234}Th	Notify HEHF	None recommended
200 rem	Same	100 x ALI	Treatment strongly recommended	Lung lavage
Plutonium				
For plutonium intakes, refer to Tables E.2, E.3, and E.4.				

(a) If soluble component is present, then urine sampling is appropriate. Use same action levels as above for soluble uranium.

E.2.3 Mixed Fission Products Intervention Levels

Mixed fission products can be detected easily by whole body counting. Minimum detectable doses for the major radionuclides encountered at Hanford are on the order of a few mrem CEDE. In severe intakes, other bioassays such as urine or fecal sampling can be implemented to provide a complete picture of the modes of clearance and retention of fission products. Cesium-137 and ^{90}Sr are the most prevalent fission products left at the Hanford Site.

Treatment (2 rem and 20 rem)

Assuming a 2:1 ratio for ^{90}Sr to ^{137}Cs, if the whole body content exceeds 2,000 nCi of ^{137}Cs at 1-day post-intake, HEHF should be notified and a spot urine sample should be analyzed for radiostrontium by emergency processing. If the whole body content exceeds 20,000 nCi, treatment is strongly indicated and a spot urine sample should be analyzed for radio-strontium by emergency processing. If it is likely that only ^{137}Cs is present, then the whole body contents suggesting or indicating treatment become 40,000 nCi and 400,000 nCi, respectively.

For ^{60}Co at 1-day post-intake (assuming class Y), if the whole body content exceeds 20,000 nCi, HEHF should be notified. If the whole body content exceeds 200,000 nCi, treatment is strongly indicated.

E.2.4 Strontium-90 Intervention Levels

Strontium is normally associated with mixed fission products at Hanford although there are some locations where it can be found without this association. Although urine sampling is most sensitive, for larger intakes measurements of the skull or whole body can be undertaken to detect the bremsstrahlung radiations from the beta emissions.

Treatment (2 rem and 20 rem)

If a second-void spot urine sample exceeds 70,000 dpm or if anything is detected in vivo, HEHF should be notified. If the second-void spot urine sample exceeds 700,000 dpm, treatment is strongly indicated.

E.2.5 Uranium Intervention Levels, Soluble Forms

Soluble uranium materials at Hanford pose a problem from chemical toxicity rather than from radiological toxicity due to the low enrichment found on the site (<1.2% ^{235}U.) A major intake of uranium should focus on kidney content and potential nephrotoxicity.

Treatment (nephrotoxicity)

An inhalation intake of about 7 mg class D or 30 mg class W uranium, should be considered potentially large enough to produce a kidney burden at or near the threshold for transient toxicity, and treatment (or at least monitoring of kidney function) should be considered. A same-day chest count should be made, and a second-void urine sample should be obtained and analyzed by emergency processing. If anything is detected in a chest count, or if the spot urine and 12-hour urine samples exceed 0.1 mg or 0.3 mg, respectively, then HEHF should be notified. Usually, the treatment for intervention is sodium or calcium bicarbonate. Monitoring of kidney function is recommended.

For wounds, excision by surgery is not usually recommended, due to the high transportability of the material. A wound with about 5 nCi (4 to 8 mg) of uranium or urine samples containing uranium at 0.1 mg (for spot urine samples) or 0.3 mg (for 12-hour samples) should involve notification of HEHF and kidney function monitoring.

E.2.6 Uranium Intervention Levels, Insoluble Forms

Uranium found in buildings 303-M, 333, and 306-W exhibits much less transportable behavior, because it is predominantly class Y material. Both 3000-second same-day chest counts and second-void spot urine samples are used for rapid estimation of the intake.

Treatment

There is no simple treatment for class Y components of the intake retained in the lung. If anything is detected in a chest count (implying a potential CEDE of 2 rem), then HEHF should be notified, although it is doubtful that any treatment will be appropriate. Lung lavage should be considered only for extremely large intakes. If the chest burden exceeds 200 nCi (600 mg) ^{238}U or 10 nCi (5 mg) ^{235}U then treatment for removal of activity in the lung should be considered. These burdens imply a potential CEDE of 200 rem or approximately 1700-rem committed dose equivalent (CDE) to the lung.

Because there can be some soluble material associated with the intake, nephrotoxicity can still be of concern for large intakes. If the second-void urine sample or the 12-hour urine sample exceeds 0.1 mg or 0.3 mg, respectively, then HEHF should be notified. (This excretion would imply that the threshold for transient chemical toxicity might have been exceeded.) Monitoring of kidney function is recommended.

Wounds that contain uranium metal exhibit a serious surface dose consequence to surrounding tissue due to beta particles (>200 mrad/h). Excision should be considered in these cases if the wound contains >15 nCi. Based on the 2-rem CEDE criterion, treatment should be considered for wounds containing about 170 nCi of ^{238}U and/or about 8 nCi of ^{235}U (assuming recycled uranium oxide form). At the same time, the urinary excretion should be watched closely because, if the material leaves the wound quickly, nephrotoxicity may be of concern.

E.2.7 Plutonium Intervention Levels

Treatment

Plutonium is treated by removal from blood and systemic organs using DTPA chelation via injection (by HEHF). This means that treatment does not affect activity in the lung to any appreciable extent, so treatment based on dose per unit intake (which is influenced by lung dose, especially for class Y material) is not as reliable an indicator of benefit. On the other hand, there is a direct correlation between DTPA, urinary excretion, and dose averted because of plutonium excreted. The CEDE dose averted per dpm excreted in urine is about 2 mrem, and the excretion enhancement factor using DTPA can vary from about 10 to 100. So if DTPA is administered when untreated excretion is 2 dpm/day, excretion should increase to 20 to 100 dpm for a dose savings of 40 to 200-mrem/day CEDE. It is probable that the efficacy of treatment will decrease with continued administration as plutonium is

removed from the liver and the rate of transfer from lung to blood decreases. Ceasing DTPA treatment when excretion drops to below 2 dpm/day probably sacrifices less than 40 mrem/day.

For wounds, refer to the preceding Table E.4. Generally, any detectable plutonium in the wound or in spot urine samples should warrant considering administration of DTPA. If the activity in the wound is >5 nCi, excision of tissue should also be considered.

E.2.8 Intervention for Ingestion of Radioactive Materials

Similar considerations for treatment or intervention levels apply to ingestion of radioactive materials as to inhalation. Exposure of the lower large intestine for poorly transported chemical species can be considerable in large intakes, but rapid clearance through the gastrointestinal (GI) tract to feces occurs. If an intake could potentially result in dose to an organ in the GI tract exceeding 50 rem, treatment should be considered.

E.2.9 Work Restrictions

Under any of the foregoing intake circumstances, a work restriction should be considered to prevent the worker from receiving further occupational radiation dose until an estimate of his/her dose is completed.

E.2.10 References

Bhattacharyya, M.H., B.D. Breitenstein, H. Metivier, B.A. Muggenburg, G.N. Stradling, and V. Volf.. 1992. *Guidebook for the Treatment of a Accidental Internal Radionuclide Contamination of Workers*. EUR 14320 EN. A joint publication for the Commission of the European Communities Directorate-General for Science, Research, and Development, and the U.S. Department of Energy, in *Rad. Prot.Dosimetry* 41:1.

International Commission on Radiological Protection (ICRP). 1991a. *1990 Recommendations of the International Commission on Radiological Protection*. ICRP Publication 60, Pergamon Press, New York.

International Commission on Radiological Protection (ICRP). 1991b. *Revised Annual Limits on Intake Based on the New Recommendations of the International Commission on Radiological Protection*. ICRP Publication 61, Pergamon Press, New York.

National Council on Radiation Protection and Measurements (NCRP). 1980. *Management of Persons Accidentally Contaminated with Radionuclides*. NCRP Report No. 65, Washington, D.C.

Glossary

The definitions contained herein are intended to be consistent and compatible with 10CFR835, DOEG 441.1-3, DOE STD 1112.98, DOE STD 1121-98, DOE STD 1098, and ANSI/HPS N13.30. Wording may differ slightly because of common site historical usage; however no discrepancy from regulatory requirements is intended.

analysis code	A code for computerized scheduling of the type of analysis desired. For example, IPU denotes analysis for ^{238}Pu and $^{239+240}Pu$.
annual limit on intake (ALI)	The quantity of a single radionuclide which, if inhaled or ingested in a working year, would irradiate a person represented by ICRP Reference Man, to the limiting value for control of occupational exposure.
bioassay	Measurement of the amount or concentration of material (usually radioactive material) in the body or in biological material excreted or removed from the body and analyzed for purposes of estimating the quantity of material in the body (according to HPS N13.30-1996).
chest measurement	Direct measurement of radioactivity deposited in the chest region. The chest measurement includes contributions from activity in the lungs and skeleton.
committed dose equivalent	The dose equivalent to an organ or tissue committed over a total 50-year period following an acute intake, or onset of chronic intake, of radioactivity.
committed effective dose equivalent (CEDE)	The sum of the products of the weighting factors applicable to each of the irradiated body organs or tissues and the committed dose equivalent to those organs or tissues.
container-not-out (CN)	A term denoting that the worker took the sample kit inside his/her residence but did not put it out on collection day.
contractual detection level (CL)	The required minimum detection level which is equivalent to the highest acceptable MDA. The CL applies to the overall process and not to individual samples.
DAC-hours	The time and concentration integrated exposure to airborne radioactivity. Exposure to 1 DAC-hour implies one hour equivalent exposure to air at the DAC value. *See also* derived air concentration (DAC).
decision level (L_c)	The quantity of radioactivity (or mass for uranium analyses) for which there is a stated probability that the measurement is not part of the blank population set..
derived air concentration (DAC)	The concentration of a radionuclide in air which, if breathed over a working year, would irradiate a person represented by ICRP Reference Man, to the limiting value for control of occupational exposure. *See also* DAC-hours.

dose assessment	The evaluation and assignment of a specific dose associated with a specific intake scenario. The dose assessment is documented using an evaluation report.
evaluation report	The formal documentation of an assessment of internal dose. The evaluation report is filed in the worker's radiation exposure file.
Exposure Evaluator (EE)	The emergency point of contact for the Internal Dosimetry Program, immediately following an incident.
failed analysis (FA)	Due to analytical problems, a valid analytical result could not be obtained. No results reported.
Field Dosimetry	The components within a contractor organization having bioassay and internal dosimetry radiation protection responsibilities.
field monitoring	Monitoring performed at facilities, including air sampling and personal contamination surveys.
head measurement	Direct bioassay measurement of the radioactive content of the head. This measurement is used to estimate the total skeleton content, and to correct a chest count to provide an estimate of lung content.
insufficient sample (IS)	A sample below the minimum contractual volume or mass for routine analysis. This sample will not be analyzed; another sample should be submitted.
internal dose	The dose equivalent to an organ or tissue, or to the effective whole body, from radionuclides taken into the body.
Internal Dosimetry	The staff within the Pacific Northwest National Laboratory who are assigned to the Hanford Internal Dosimetry Program.
Internal Dosimetrist	The individual responsible for assessing and documenting internal dose.
in vivo measurement	Direct measurement of radioactivity in the body.
kit	A package containing bioassay sample containers. Usually one kit is used for each sample, but sometimes two kits are used to obtain one 24-hour total sample (work fraction and home fraction).
kit code	A code designating the type of sample to be collected. (See Appendix B, Table B.4, for a comprehensive list of kit codes.)
lost container (or lost kit)	A sample kit that was not retrievable by the Analytical Services Laboratory. A "container-not-out" becomes a lost kit if it is not retrieved in 5 days.
lung count	Direct bioassay measurement to determine the activity in the lung. The measurement is determined from the results of a chest count minus the activity that is contributed from the skeleton.
minimum detectable	An estimate of the smallest quantity that can be measured in a sample

activity (MDA)	such that the risk for false detection and false nondetection are each 5%.
non-stochastic effects	Effects for which the severity increases with dose, and for which there may be a threshold dose below which the effect does not occur. (*Same as* deterministic effects.)
no sample (NS)	A kit that was not used and remained outside the residence on collection day. The Analytical Services Laboratory notifies Internal Dosimetry of a "no sample" within one day so that rescheduling can occur, if necessary.
not evaluated	Sample was collected but not analyzed. Typically used when a backup sample was obtained but analysis was determined to be unnecessary and the sample discarded.
oral reporting level	The minimum level of a bioassay measurement result at which the measurement laboratory shall provide prompt verbal or electronic notification to Internal Dosimetry.
organ dose equivalent	The assessed dose equivalent to an organ or tissue of the body.
processing code	The desired turnaround time for the analysis. A shorter turnaround time results in less sensitivity and/or higher cost. Four processing categories exist, but not all radionuclide analyses are available for each category. (See Section 6.0, Tables 6.1 through 6.5.)
Radiation Records	The sitewide support program, operated by Pacific Northwest National Laboratory, which maintains occupational radiation records for the Hanford Site.
reason code	A computer code used to describe the reason that a bioassay measurement is performed. (See Appendix B, Table B.3)
screening level	The minimum level of a bioassay measurement at which some further review or action is advantageous to determine whether follow-up measurements or dose assessment is needed.
sequential analyses	More than one radiochemical analysis performed on a single sample. For example, IPS is the analysis code for an IPU analysis and a ^{90}Sr analysis performed on the sample.
statement of work (SOW)	The technical and administrative specification of work to be performed under contract by the Analytical Services Laboratory.
stochastic effects	Effects for which the probability of an effect occurring, rather than its severity, is a function of dose, without threshold.
total effective dose equivalent (TEDE)	The sum of the effective equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).
whole body measurement	Direct bioassay measurement to determine the amount of high-energy, gamma-emitting radionuclides in the total body.

Acronyms and Abbreviations

AMAD	activity median aerodynamic diameter
ANSI	American National Standards Institute
ALI	annual limit on intake
CEDE	committed effective dose equivalent
CL	contractual detection level
CN	container-not-out
DAC	derived air concentration
DAC-hours	time-integrated exposure to airborne contamination
DEMS	Dose Evaluation Management System
DOE	U.S. Department of Energy
DPI	days post-intake
DTPA	diethylenetriamine pentaacetic acid
EDF	Emergency Decontamination Facility
EE	Exposure Evaluator
EPA	U.S. Environmental Protection Agency
ER	environmental restoration and remediation
FA	Failed Analysis
GI	gastrointestinal
HEHF	Hanford Environmental Health Foundation
Historical Files	Hanford Radiation Protection Historical Files
HPS	Health Physics Society
HPDAC	Hanford Personnel Dosimetry Advisory Committee
HRRP	Hanford Radiation Records Program
HRRPL	Hanford Radiation Records Program Library
ICRP	International Commission on Radiological Protection
IDP	(Hanford) Internal Dosimetry Program

INTERTRAC	Internal Dose Tracking System
IS	insufficient volume sample
IVMP	In Vivo Monitoring Program
IVRRF	In Vivo Radioassay and Research Facility
Lab	Analytical Services Laboratory
LC	lost container
MDA	minimum detectable activity/amount
MDD	minimum detectable dose
NCRP	National Council on Radiation Protection and Measurements
ND	not delivered
NIST	National Institute of Standards and Technology
NS	no sample
ORL	Oral Reporting Level
ORP	DOE Office of River Protection
PNNL	Pacific Northwest National Laboratory
POC	Patrol Operations Center
QA	quality assurance
QC	quality control
REIRS	Radiation Exposure Information Reporting System
REX	Radiation Exposure (System)
RL	DOE Richland Operations Office
RPT	Radiation Protection Technologist
SOW	statement of work
STL	Severn Trent Laboratories
TEDE	total effective dose equivalent
WB	whole body
WBC	whole body count