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November 12, 1992

Mr. John H. Austin
United States Nuclear Regulatory Commission
Mail Stop 5R2
Washington, DC 20555

re: License No. SMB-1393
Site Characterization Plan

Dear Mr. Austin:

Please find enclosed our site characterization plan for Unocal Molycorp's Washington, PA facility.

Sincerely,

Barbara K. Dankmyer
Resident Manager

cc: C. Glenn, NRC
J. Kinneman, NRC Region I
D. Shoemaker

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Plan for Site Characterization in Support of Decommissioning of the Molycorp Inc. Washington, Pa Facility

Submitted to the U. S. Nuclear Regulatory Commission,
Division of Low Level Waste Management and Decommissioning

by

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with assistance in the preparation by

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Table of Contents

1. INTRODUCTION

The Nuclear Regulatory Commission has included the Molycorp plant site at Washington, PA, among the more than 40 nuclear material sites under the 1990 Site Decommissioning Management Plan (SDMP). As part of its ongoing efforts to comply with the SDMP and to move toward decommissioning and de-licensing of the site, Molycorp and its consultants have developed this Site Characterization Plan. A primary objective of this plan is to adhere as closely as possible to the recommendations and format described in the NRC Branch Technical Position entitled "Site Characterization for Decommissioning Sites, July, 1992." The organization of this document follows the general outline adopted by the Branch Technical Position (BTP). Because there are sections in the BTP that do not apply to the Molycorp site, the paragraph numbers is this document do not correspond directly to those of the BTP. The Site Characterization Report, which will be submitted for review to the NRC after the site characterization study has been completed, will also follow the format outlined in the BTP, to the extent that such a format is practical.

1.1 Objectives of the Site Characterization

In developing the plan for this site characterization, Molycorp has considered several conceptual plans for decommissioning, the type and extent of existing radiological contamination and the potential for long-term exposure of humans after the site is released for unrestricted use. The main objectives of site characterization proposed here in support of decommissioning are:

1. To quantify the physical and chemical characteristics of radiological contamination and the extent of contaminant distribution including rates of migration of Th and its daughter products.

2. To identify and measure environmental parameters that significantly determine potential human exposure from existing radiological contamination under the condition of unrestricted use. For example, it is necessary to measure the rate of leaching of Th, U and Ra nuclides from the glassy slag formed at high temperatures, which characterizes the contamination of this site, in order to evaluate the potential release of radionuclides to ground water, surface water and eventually humans deriving their water intake from surface waters.

3. To support the evaluation of alternative decommissioning actions and detailed planning of a preferred approach for decommissioning, decontamination and waste disposal. The site characterization plan includes the dose assessment activities needed to evaluate the efficacy of alternate decommissioning plans.

1.2 Relevant NRC Guidance

The site contains low level Th wastes in a glassy slag distributed in a spectrum of particle sizes from large pieces several inches across to small particles, both buried in conformity to the NRC Branch Technical Position on "Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations" (46 FR 52601) and also stored above ground in a segregated and vegetationally stabilized slag pile. Based on a limited underground survey (RSA, 1990) (32 boreholes) the Th waste buried under and adjacent to the eight holding ponds on the west side of the site meets the option 4 limits at all locations surveyed and on the average, meets option 2 limits. Local hot spots underground generally do not exceed the option 2 limits by more than a factor of 10. A more extensive underground survey covering the rest of the affected areas of the site is described in sections 5.2 and 5.4.

The following documents will be used to assess whether the characterization program proposed will be sufficient to ascertain compliance with the recommendations therein.

1. Options 1 and 2 of the Branch Technical Position "Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations" (46 FR 52601; October 23, 1981).

2. "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source or Special Nuclear Material," Policy and Guidance Directive FC 83-23, Division of Industrial and Medical Nuclear Safety, November 4, 1983.

3. "Termination of Operating Licenses for Nuclear Reactors," Regulatory Guide 1.86, June 1974, Table 1, for surface contamination of reactor facility structures.

4. The Environmental Protection Agency's (EPA's) "Interim Primary Drinking Water Regulations," 40 CFR part 141 (41 FR 38404; July 9, 1976).

5. EPA's "Persons Exposed to Transuranium Elements in the Environment" (42 FR 60956, November 30, 1977). This document provides guidelines for acceptable levels of transuranium elements in soil.

1.3 Planning for Site Characterization

Personnel from Molycorp, from Radiation Surveillance Associates, Inc. (RSA), and from Vail Engineering will collaborate to produce the site characterization plan, to conduct the site characterization study, and to write the site characterization report. Molycorp personnel B. Dankmeyer, Resident Manager, G. Dawes, plant Health and Safety Supervisor, and D. Shoemaker, Manager of Molybdenum Operations, will address issues associated with site location, history, current conditions, and future plans. Personnel from RSA, Inc. will carry out radiation studies (M. E. Wrenn, Ph.D., C.H.P., health physics, radiation measurements, dose assessment; W. Delaney, environmental radiation surveys; and L. Bertelli, Ph.D., mathematical modeling for internal dose assessment). Vail Engineering (Ralph Vail) will characterize surface and subsurface hydrology and contaminant transport. Consultants with specialties in meteorology, land use, and demographics will be retained to carry out characterization activities relevant to their disciplines.

This group will assemble and review available information on site history, the physical environment, the type and extent of radiological contamination and the location of potentially exposed populations.

In the view of Molycorp and its consultants, the purpose of the site characterization study is to furnish information which can serve as a basis for evaluating alternatives for decommissioning. The site characterization report (SCR) will present the results of the site characterization study. The decommissioning alternatives will be addressed in an initial report on 3/1/93 and in the subsequent decommissioning plan, not in the site characterization report.

The planning for site characterization is greatly simplified at the Molycorp site due to the amount of site characterization data already available. This data is contained in the 1990 report on the pond area by RSA, Inc., the 1985 report by Oak Ridge Associated Universities, and the historical information dating from the 1971-1973 work by Applied Health Physics to clean up the site and consolidate the thorium slag into the existing pile. The site characterization study will expand upon this knowledge base by extending the study area to include all potentially affected areas on-site, increase the density of measurements, and provide the basis for dose assessment. Since much is already known about the site, it is unlikely that the study will produce any "surprises." It is therefore anticipated that a single site characterization study should yield sufficient information needed to design an adequate decommissioning plan, and that no or limited iterations in the site characterization processes will be indicated.

2. GENERAL INFORMATION

2.1 Site Background

The SCR will provide information describing the specific site location, site history and previous investigations relevant to radioactive and hazardous waste activities. Such information will include maps, drawings and aerial photographs. This generic background information will be useful in the process of dose assessment and development of a decommissioning plan.

2.1.1 Site Location and Description.

The following information on site location and description will be provided:

(a) Specific site location, including street address, nearest town, local political jurisdiction (e. g., county, township, borough, district), State, U. S. Geological Survey (USGS) 7 1/2 minute quadrangle and distances and directions of the site to reference points or coordinates.

(b) General area, dimensions and locations of contaminated areas on and under the site, and any contaminated areas offsite (additional detail on contamination will be provided from the surveys proposed in section 5).

(c) Site ownership, boundaries and surroundings, including roads, railroads, utility lines, drainage ways, canals, sites of historical significance and other features that could affect the conduct or effectiveness of decommissioning activities. These features will be shown on a map of the site and vicinity.

(d) Topography of the site and its immediate surroundings, including hydrogeologic features such as rivers, dams, wetlands, drinking and supply water intakes and locations of offsite population centers. Topographic maps will be at a scale of 1:200 with a contour interval of about 5 feet (or other interval that appropriately indicates the relief and grades on and immediately adjacent to the site), along with the portion of the 7 1/2 minute USGS Quadrangle that contains the site and its immediate surroundings.

2.1.2 Site History

This section of the SCR will summarize all known significant historical facts and records that may affect the design of decommissioning actions or help explain the nature and extent of site contamination. This information includes existing records of site conditions prior to licensed activities, operation of the facility, records on effluents and onsite disposals and significant incidents of releases or spills. Specifically, this information will include:

(a) Records about onsite activities and past operations involving operations such as generation of FeCb slag, burial of slag on site, and historical efforts aimed at remediation, consolidation and impoundment, and disposal of Th bearing materials. Past operations will be summarized in chronological order along with type of permits and/or approvals that authorized these operations. Estimates of the total activity of radioactive material released or disposed of on the site and its physical and chemical forms will also be included.

(b) Summaries of historical work aimed at characterizing the site and summaries of previous site monitoring programs, including sampling and analytical records of environmental monitoring programs reported for the site or the immediate surroundings.

(c) Records of relevant inspections, surveys, and investigations conducted on-site.

(d) Historic aerial photographs and site location maps showing previous site development and activities (as available).

2.2 General Physical Setting

The intent of this section is to provide a summary overview of the site characteristics. The SCR will summarize the general physical setting of the site, including general physical characteristics of the site and its proximity to people who potentially could be affected by existing contamination or decommissioning activities.

2.2.1 Physical Site Characteristics

The section will summarize the following physical characteristics in general terms:

- Climate (e.g., temperature and precipitation).

- Geologic setting (e.g., unconsolidated deposits and bedrock strata).

- Vegetation (e.g., unvegetated, forested, grassy).

- Soil (e.g., composition, thickness, chemistry).

- Groundwater (e.g., depth, quality, uses and direction and rate of flow).

- Location and description of surface water (e.g., type, flow rates, quality and uses).

2.2.2 General Information on Exposed Populations

This section of the SCR will provide a summary description of the general characteristics of potentially exposed populations. These characteristics include:

- General distribution and number of people near the site.

- Current land use(s) adjacent to the site.

- Anticipated future land use(s) on and adjacent to the site.

- Location and characteristics of any subgroups of special concern.

2.3 Preliminary Evaluation of Contamination

This section of the SCR will summarize the extent and characteristic of known or suspected site radiological contamination. This summary should be based on analysis of historic operational data, records of slag disposal that may have resulted in site contamination, existing monitoring and survey data and direct observations of the site and its vicinity. This information will be used in:

- Identifying buildings and equipment that require survey for contamination due to historical use in the processing of FeCb slag, or which may have been constructed on top of Th bearing soils;

- Designing radiation surveys for buildings, for equipment, for surface and subsurface soils;

- Designing sampling and testing programs for surface water and groundwater;

- Determining principal radionuclides of concern and relative hazards;

- Identification of applicable cleanup criteria and comparison between known or suspected contamination levels and the criteria; and

- Identification of potential occupational hazards associated with site characterization and decommissioning activities.

3. Dose Assessment

Dose assessment is a necessary element in the site decommissioning process for the Molycorp, Washington, PA plant site in order to establish the clean-up criteria necessary to allow unrestricted release upon de-licensing of the facility. Due to the highly insoluble nature of the slag (which contains the radioactive contaminants present on the site), the clean-up criteria required to keep potential dose to exposed populations within acceptable limits will probably be less restrictive than that which would apply to facilities where radioactive contaminates are more mobile. The site characterization study, therefore, must produce sufficient data to permit full evaluation of the potential dose to humans for the various decommissioning alternatives that will be examined as a part of the development of the site decommissioning plan.

The site characterization report, which will be submitted for review to the NRC upon completion of the site characterization study, will contain dose assessment analysis aimed at calculating threshold clean-up criteria necessary to keep the potential dose within accepted limits. These calculated clean-up criteria will represent the level to which the site must be cleaned in order to achieve de-licensing (that is, the projected post decommission conditions). The report will also contain the results from the site characterization study, which will be aimed at quantifying the concentration and spatial extent of thorium currently present on site (the pre-decommissioning scenario). This quantification of both the pre-decommission conditions and the projected post-decommission thorium concentration on site will allow calculation of the amount of clean-up needed to de-license the site. The results of the site characterization study will be used to identify the source terms and the pathways, and to calculate the dose conversion factors.

The site characterization study will also produce sufficient data to expand analysis to other scenarios. This expanded scenario analysis may be necessary to support the de-commissioning plan that will be developed after the site characterization report is completed.

To conduct the dose assessment, it is necessary to identify and characterize the source terms and the relevant pathways leading to internal and external exposure. The dose assessment in the site characterization report will include calculations using the program RESRAD, which was designed at Argonne National Laboratory to derive site specific guidelines for allowable residual concentrations of radionuclides in soil. The input data for the dose assessment, which will be collected as part of the site characterization study, is outlined in sections 3.1 through 3.3. The RESRAD program is deterministic, not probabilistic, and as such the degree of conservatism in the results is unspecified, but could be very large. Therefore, we will seriously consider using programs which use the best estimates of parameters and a measure of dispersion about the mean or geometric mean in order to derive probability distribution factors describing expected dose. Indeed, NCRP-50 warns against the pitfalls in using deterministic models such as those employed in RESRAD.

In addition, the MILDOS program will be evaluated for its utility in dose assessment for airborne exposure.

3.1 Source Terms.

In the case of the Molycorp, Washington, PA facility, the source term for the dose assessment can be defined as the residual concentration of thorium in surface and sub-surface soils. Quantification of the source term requires measurement of several parameters. (See Section 5 for a discussion of the survey and measurement procedures to be used in gathering this data). The specific parameters to be quantified are:

(a) Residual radionuclides in surface and subsurface soils and water.

(b) Levels of external gamma radiation (both surface and sub-surface).

(c) Concentrations of airborne radioactivity, including resuspendable particulate matter, radon, thoron , and their respective daughter products.

3.2 Identification of Pathways.

The site characterization study must include sufficient data to identify the pathways that make significant contributions to the dose to potentially exposed populations. The significance of each pathway is a function of the rate of migration along the pathway. The site specific data necessary to quantify the rates of migration, such as leachability and emanating properties, will be obtained by the survey and measurement procedures discussed in Section 5. Other necessary data are available in the literature. The site specific pathways to be examined as potential exposure routes will include the following.

The most likely to be important are:

(a) External gamma radiation exposure from soils.

(b) Inhalation of airborne resuspendable particulate matter.

Because of the extreme insolubility of the slag, the following are expected to be less important:

(c) Migration from slag to surface and sub-surface soils, and to groundwater. These migration rates will be determined by leachability studies.

(d) Ingestion of groundwater.

(e) Inhalation of emanation products. (Daughters of Radon and Thorium.)

(f) Migration from groundwater and soils to vegetable and meat products.

Site specific pathway mechanisms will be characterized either by measurements made on-site, laboratory analysis of samples taken from the site, and/or by use of models and data reported in the literature or developed directly for this site.

3.3 Characterization of the Physical Setting and Identification of Potentially Exposed Populations.

To complete dose assessment a profile must be developed of the physical layout of the plant site and of the possible distributions of the population that may be expected to arise on and around the plant site after decommissioning is accomplished. A qualified contractor will be engaged to study the demography and land use patterns around the site (see Section 4.5). The radiological impact of these land use and demographic factors upon the pathway analysis will be evaluated.

4. PHYSICAL CHARACTERISTICS OF SITE

During the site characterization study, the physical characteristics of the site will be documented following, in general, the guidelines presented in the NRC's Branch Technical Position on Site Characterization (July 1992). Vail Engineering will carry out the tasks associated with documenting the hydrology and hydrogeology of the site. Documentation of the demography, the geology, the meteorology and climatology, and the land use patterns of the region surrounding the site will be done by a qualified contractor. Map making tasks will be carried out by RSA, Inc., and/or a qualified contractor.

4.1 Surface Features

This section of the SCR will describe the present topography of the site and immediate vicinity supported by topographic maps of appropriate scale and contour intervals. The maps will also depict significant surface features such as depressions, buildings, roads, wetlands, creeks, landfills, ditches, and drainage systems. Topographic maps will be at 1:200 scale, or at other appropriate scales as required to depict the major surface features of the site relative to decommissioning. The contour interval will be no greater than 5 feet, and the maps will use conventional nomenclature and symbols.

4.2 Meteorology and Climatology

The SCR will provide baseline information describing "variation in seasonal" weather conditions at the site. Such information may be needed to assess the rainfall for the site and to evaluate the transport rates through the airborne and waterborne pathways. The information will also be used to evaluate impacts from long-term releases of radionuclides if any soluble species are found for this site and source. The meteorological and climatological parameters and data which will be reported include:

- Speed, directions, and variability of winds (presented as a wind rose diagram and, if available, the Pasquill atmospheric variability category);

- Amount, type, and distribution of annual precipitation;

- Estimates of pan evaporation and evapotranspiration (if available); and

- Records of severe weather conditions, such as tornadoes, hurricanes, drought, and flooding, that might affect the stability of the contaminated material before , during, and after decommissioning.

4.3 Surface Water Hydrology

The SCR will evaluate surface water at and near the site, and the effects of surface water processes on transport of contaminants. The site characterization program will address both general characteristics of surface water near the site and on-site flow patterns. The information on surface water will include the following:

(a) Characterization of Chartier's Creek, including flow rate, volume, and macrochemistry. Proximity and transport between Chartier's Creek and the site contamination will be discussed.

(b) Historic data on peak discharges and water levels. This data may include, if available, information on stage/discharge relationships, and recurrence intervals of flooding for Chartier's Creek, as well as stages, flow rates, and flow velocities for severe flooding events. This information will be useful to investigate or model the stability of the long lived radioactivity material in the slag pile and buried on-site. Such information may be used in the site decommissioning plan to demonstrate that proposals to leave material on-site provide reasonable assurance that waste will remain sufficiently isolated from the human environment for long time periods, on the order of 1000 years.

(c) Locations, areas, and dimensions of wetlands, the 100 year flood plain, and watershed divides on or in the immediate vicinity of the site. Surface erosion and potential contaminant transport associated with such surface processes will be addressed.

(d) Current inventory of surface water uses within approximately 10 kilometers of the site. The SCR will not purport to inventory all water uses within a 10 km radius of the site, but it will provide a representative sampling based on available data.

(e) Estimated potential for contamination of surface water bodies above specified radiological water quality criteria. The potential for significant transport will be evaluated using a model representative of the local hydrogeologic system. Because of the insolubility of the radionuclides in the slag, the potential for significant transport is so minimal that a semi-quantitative analysis of potential surface water transport may suffice.

4.4 Geology

The SCR will sufficiently describe the site geology to support assessment of the long-term stability of the site (since on-site disposal is an option), groundwater transport of contaminants, and the selection of background soil and water samples. Geologic site information will be presented in two categories: reconnaissance information on the region surrounding the site, and site specific geologic characteristics.

4.4.1 Regional Geology

The site characterization report will include a section on the regional geology that shows the relationship between the local geology of the site and that of the surrounding region. If obtainable without the performance of prohibitively costly studies, this section will include:

- A general stratigraphic chart for the area depicting major formations and their thicknesses and characteristics.

- A geologic map depicting the bedrock geology that covers the region around and including the site.

- A geologic cross-section that is keyed to the geologic map and depicts the principle structures and geologic formations beneath the site.

In addition, the summary of regional geology will include the following information:

(a) Geomorphology: information on the physiographic province that contains the site and prominent topographic features within 10-20 km from the site.

(b) Stratigraphy and Lithology: this includes regional stratigraphic units and regional bedrock formations.

(c) Structure and Tectonics: significant geologic structures and their association with any active tectonism. Such features may include faults, folds joints, cleavage, and major fractures. Information on the current tectonic stability of the region and historical records of seismic activity will be presented if available from the USGS, the state geological survey office, local universities, or other similar sources.

4.4.2 Site Specific Geology

The SCR will describe the site specific geologic characteristics in a manner similar to the regional geologic description. The site-specific description, however, will focus on details of site geology and its effect on long-term release and transport of radiological contaminants and stability of residual materials. The following site-specific geologic information will be included in the SCR:

(a) Geomorphology: The object of the study of the geomorphology of the site will be to ascertain the potential for migration of radionuclides by surface erosion into Chartier's Creek, since this is the most likely path of migration for this particular site. To this end, the SCR will include maps and other analysis characterizing such geomorphic features as on-site relief, surface gradient and topography, soil weathering profile and associated surface deposits, and local drainage basins and channels. The description of the fluvial geomorphology of the site will be linked to the hydrologic characterization in Section 4.3.

(b) Stratigraphy and Lithology: The stratigraphic units at the Molycorp, Washington, PA site that are potentially affected by radiologic contamination are (1) fill, consisting of FeMo slag, FeCb slag, and various other materials, in layers between 0 and 10 to 12 feet thick; (2) sediments, clay, and unconsolidated materials going down to about 20 feet in depth; and (3) bedrock, at about 20 feet, as indicated by auger refusal during drilling of boreholes. Because the Th bearing slag on-site is very insoluble and therefore very immobile, it is probable that the potential for radiological impact is limited to these strata. A high density of boreholes (more than 300) will be drilled as part of the radiologic survey of the site (see section 5.2.1). Data from the drilling logs from this drilling program will serve as the basis for detailed descriptions of these potentially impacted strata. Borehole locations and stratigraphic profiles will be presented on geologic maps and cross sections. Drilling logs for all boreholes drilled on-site will be included as an appendix to the SCR , and these logs will include borehole profiles indicating the variation with depth of stratigraphic features.

Lithologic studies on-site will be confined to sampling the bedrock to obtain information on it's mineralogy and other characteristics. Since no other lithologic features are impacted by the site, the bedrock is the only feature that needs to be studied.

(c) Site Structural Features and Geologic Stability. Since the Molycorp, Washington, PA site is relatively small (about 15 acres), and the bedrock is known to be level, shallow, and at a fairly uniform depth (about 20 feet) across the site, it is unlikely that major discontinuities or fracture systems that could influence radiologic contaminant transport exist on-site. Agencies such as the USGS and the state seismology office will be consulted to determine if any major faults, fractures, or other discontinuities or known and documented in the section of the Chartier's Creek drainage containing the site. The results of such inquiries will be described in the SCR.

(d) Geologic Stability: estimates of the long term stability of the site. Site stability will be evaluated by estimating the maximum ground motion that can reasonably be anticipated at the site, based on historical records of seismic events, and considering other geologic indications of active processes during the Holocene period that could significantly affect site stability.

4.5 Demography and Land Use

4.5.1 Demography

The population data for the area surrounding the site that is needed for assessing dose and socioeconomic impacts of radiological contamination includes:

(a) Residence Inventory. Since the Molycorp, Washington, PA plant site is located in an urbanized area, it would be costly and of no practical value to identify the location and number of all residences within a 2 km radius of the plant, as suggested in the NRC Branch Technical Position. Instead, populations in the vicinity of the plant will be documented using such techniques such as maps showing population density isopleths, and aerial photographs. Any sensitive populations within a 2 km radius (e.g., medical institutions and schools) will be identified. The nearest residences will, of course, be identified.

(b) Transient Population: The SCR will document daily and seasonal variations in the baseline population within a radius of 2 Km of the site, due to influxes associated with work, education, and other normal human movements.

4.5.2 Land Use

This section of the SCR will evaluate the type of land use at the site and in the surrounding vicinity. Land use information will be useful in constructing dose assessment scenarios and limiting off-site exposure during decommissioning. The type of land use will be categorized into one or more of the following types: residential, industrial, agricultural, and special use. For agricultural uses, the SCR will identify the specific uses of the land, for example, grazing, dairy farming, or crop production.

4.6 Hydrogeology

Previous studies have established the general characteristics of the shallow ground water regime in the plant area: 1) The direction of the ground water flow is from the east across the plant area with discharges to Chartier's Creek. Chartier's Creek flows in a northerly direction along the westerly boundary of the plant site. 2) The water table generally lies from a few feet to approximately ten feet below the ground surface. 3) The FeCb slag is primarily contained within the surface soils, the fairly thin vadose zone and the upper few feet of the shallow water aquifer. 4) Flow is primarily limited to the shallow water aquifer. This aquifer extends from the water table elevation to the top of bedrock. The bedrock generally lies at a depth of less than twenty feet below the land surface. 5) Original natural soils of the shallow water aquifer are fairly low permeability silt and clay loams of alluvial origin. In some areas, the upper several feet of the soil has been altered by distribution of cinders, slag and other fill materials during plant development and operation. 6) The natural silt and clayey soils of the shallow aquifer have an average permeability on the order of 3×10^{-3} cm/sec. The cinder and slag deposits increase the overall conductivity of the aquifer to the equivalent of an alluvium with a permeability on the order of 4×10^{-2} cm/sec. This indicates that the total shallow ground water flow through the plant area averages on the order of 40 gallons per minute.

The SCR will be based on such additional field investigations and soils analysis as are necessary to describe and quantify the ground water regime and transport mechanism pertinent to mobilization and attenuation of contaminants resulting from past plant operations.

4.6.1 Identification and Characterization of Hydrogeologic Units

Each soil unit from the surface to and including the upper strata of the underlying bedrock formation shall be identified and described with specific data relative to flow characteristics and lateral and vertical extents. Particular emphasis shall be given to analysis of the upper portion of the shallow water aquifer where the natural soils have been altered by deposition of fill materials and other debris.

4.6.1.1 Soil Characterization. Determinations of the primary soil characteristics shall be made for each pertinent soil unit and the SCR shall include the general physical and pertinent hydrological properties of the soils relative to mass transport characteristics, soil reaction characteristics, soil contaminant properties and soil engineering characteristics.

4.6.1.2 Vadose Zone Characterization. The vadose zone in the plant area is relatively thin.. It is of significant importance, however, because it and the surface soils contain the bulk of the radioactive contaminants. The vadose zone will be analyzed and described relative to infiltration rates and other characteristics affecting the potential for mobilization, transport and attenuation of contaminants.

4.6.1.3 Saturated Zone Characterization. The shallow water aquifer shall be described in detail. Particular emphasis will be made of the hydrological properties of the shallow water aquifer down gradient from the contaminant sources.

During the subsurface survey described in section 5.2.2 of this plan, water level measurements will be made and water samples collected at many of the boreholes. A determination of the pH and conductivity will be made for each water sample and additional analysis made of the water chemistry of selected samples. The soil samples and logs of each borehole will be inspected relative to hydraulic properties. The data obtained will provide considerable detail on the water table configuration and the distribution and flow travel paths of non-radioactive contaminants.

A well will be drilled and completed in the shallow water aquifer upgradient of the plant area for determination of ambient water quality.

A well will be drilled and completed in the upper portion of the bedrock formation underlying the shallow water aquifer in the northwestern part of the plant area. The well shall be tightly sealed to cut off flow from the overlying formation. Drilling methods will be selected to minimize disturbance of the hydraulic conditions of the deeper aquifer and to prevent contamination of the ground water. Water levels in the well will be accurately measured and recorded relative to both surface elevation and water levels in adjacent shallow wells. Monitoring of static water levels will be conducted over an extended period of time to determine the magnitude and direction of any vertical hydraulic gradient and to indicate the degree of hydraulic connection between the aquifers. Atmospheric pressure will be recorded along with water levels and such shall be analyzed for evidence of a confined, deeper aquifer. Water analysis will be made to determine if there is migration of contaminants into the lower aquifer from the overlying groundwater. Water level down draw and recovery well tests shall be conducted to determine the hydraulic characteristics of the deeper aquifer. During such tests, water levels will be monitored in adjacent shallow holes for additional evidence of the degree of hydraulic connection between the aquifers.

Investigation of the bedrock aquifer will be extended if evidence is found that contamination is present or is likely to occur in the deeper formation.

Prior investigations indicate that the majority of the shallow ground water flow may be conducted by the irregular and non-continuous cinder and slag deposits in the upper part of the shallow aquifer. This condition results in an aquifer that has hydrological characteristics that, in many aspects, are more similar to fracture following flow paths of rock formations than that of homogeneous porous soils. Well pump tests under such conditions are generally of little value in the determination of general aquifer transmissivity and average formation and discrete flow path water velocities. The final determination of total shallow ground water flow and effective travel times will be based on modeling.

Historical data from the monitor wells will be analyzed to determine if events in plant areas may have resulted in noticeable chemical changes in the ground water and which could indicate the average ground water velocity along discreet flow paths.

Additional soil and water quality analysis will be made as necessary to describe and document in the SCR, the saturated zone characteristics of the shallow water aquifer for the pertinent parameters set forth in the guidelines.

4.6.2 Groundwater Flow and Transport Models.

Determination of the flow and transport models to be used for the SCR will be made after evaluation of other data prepared for the report. In particular, evaluation will be made of the borehole logs and pump tests to determine if the model program should be designed to simulate fracture following or alluvium type soil flow characteristics or a combination of the two. The model or models must have the capability for input of multiple or wide spread contaminant source. Additional analysis will be required to determine if the model program needs to reflect mobilization and attenuation of contaminant transport which may result from significant changes in ground water pH and other chemical concentrations.

The model program output will be carefully checked against field observations of the disbursement and concentrations of indicator chemical concentrations in the groundwater. Adjustments will be made to the input data and the model program as required to insure that the model reasonably reflects the site specific contaminant transport characteristics and indicates reliable long term site conditions.

4.6.3 Hydrogeologic Characterization Methods and Monitoring Practices and Procedures

This section will include a description of all hydrogeologic site characterization activities, methods and monitoring installations sufficient to demonstrate that the site characterization methods and devices provided data that are representative of site conditions. The SCR will describe the monitoring practices, procedures and quality assurance programs used to collect water quality and hydraulic data. Monitoring well descriptions will include location, elevation, screened intervals, depth, construction and completion details and the hydrologic units monitored.

5. Extent and Concentration of Contamination

The characterization of the extent and concentration of radiological contamination at the Molycorp, Washington, PA plant site falls into three broad categories of tasks.

(1) Analysis of physical, chemical, and radiological characteristics of FeCb slag. Section 5.1 contains the portion of the site characterization plan that provides for this category of analysis.

(2) Documentation of the physical extent of Th bearing FeCb slag distribution , of radioactivity in surface and subsurface soils, and in buildings and equipment. Sections 5.2, 5.4, and 5.6 describe the plan for documenting the physical distribution of radioactivity and radiation from FeCb slag on site.

(3) Analysis of the concentration and rate of dispersal of contamination from thorium and its daughter products derived from FeCb slag in air, and in surface and subsurface water. Sections 5.3, 5.5, and 5.7

provide the plan for characterizing current concentrations of radionuclides in airborne and waterborne pathways.

5.1 Characterization of Source

The sampling and analysis program described in this section of the site characterization plan will document the physical and chemical properties of Th bearing FeCb slag which contains smaller amounts of Uranium and its daughter products, which is the only known radiological contaminant present at this site.

A great deal is already known about the site. For example The inventory and concentration of ^{232}Th has already been measured in the above ground slag pile on the southern section of the site. Based upon the Applied Health Physics report (May 22, 1975) and their analyses of activity by gamma spectrometry the concentration of ^{232}Th is 1250 pCi/g and the total inventory is 12.7 Ci. The slag is present in a stabilized configuration in a pile covered with vegetation and with a volume of 249,000 cubic feet and a density of about 90 pounds per cubic foot.

Gamma exposure rates have already been measured over much of the surface of the site (ORAU Report, June 1985) and on the surface and subsurface in the areas around the ponds (RSA Report, Dec. 1990).

5.1.1 Chemical Composition of Slag

The process employed at the Molycorp plant that formed the FeCb slag involved a highly exothermic reaction that produced FeCb from ore imported from Araxa, Brazil. The Araxa ore contained natural Th as an unwanted trace constituent. The ore was reduced to metallic form in the reaction and shipped as product for use as an alloy in the production of specialty steel. The trace Th remained in the slag, which, as an unwanted by-product of the reaction, was retained on-site.

5.1.1.1 Ingredients. The Site Characterization Report will describe the ingredients and reagents used in the reaction that formed the FeCb slag and it will describe the normal amounts and proportions used.

5.1.1.2 Chemical reaction. The SCR will contain a description of the chemistry of the reaction that formed the slag.

5.1.1.3 Determination of Chemical Composition of Slag. A chemical analysis will be performed on a sample of FeCb slag, and the results will be reported in the SCR

5.1.2 Radiochemical Composition of Slag

Laboratory analyses will be performed to determine the radiochemical and isotopic composition of both the Araxa ore and the FeCb slag.

5.1.2.1 Radioelements in Cb Ore. The radiochemical composition and the relative abundance of naturally occurring radionuclides in Cb ore will be reported from the literature (if available).

5.1.2.2 Testing of an Historical Ore Sample. If a representative unprocessed ore sample dating to the time of FeCb production at the Molycorp plant site can be found, the relative abundance of radioactive isotopes will be measured, in the manner described in Paragraph 5.1.2.5.

5.1.2.3 Measurements of Radionuclides in Slag. In order to assess the radiological impact of residual FeCb slag remaining on the Molycorp site, it will be necessary to measure the degree of equilibrium in the uranium and thorium series radionuclides, and the ratio of U to Th, in the slag.

For thorium radioactive equilibrium in slag will be determined by dissolution, radiochemical separation, and alpha spectrometric analysis. This will also provide an analysis for ^{230}Th which is a uranium series radionuclide. A preliminary analysis of Th isotopes in one slag sample is shown in Figure 5-1. It can be seen that ^{232}Th and ^{228}Th are in equilibrium and that the relative activity of ^{230}Th from the uranium series is about 10% of the ^{232}Th activity.

5.1.2.4 Sampling of Slag. Samples of FeCb slag will be taken from the slag pile, one at each end and one at the center, and three will be chosen from other areas of the site. Two of these last three samples will be samples of slag which was crushed in the past, pumped to a settling basin and subsequently used as fill. Six samples will be analyzed radiochemically, and will be tested for leaching of Uranium and Thorium isotopes , for ^{226}Ra and ^{228}Ra and for emanating power of ^{222}Rn and ^{220}Rn..

5.1.2.5 Analysis. In the analysis technique to be employed for FeCb slag and ore samples, the material will be first completely dissolved in HF and HNO3 and then $^{234,238}U$ and $^{232,230,228}Th$ will be analyzed by radiochemical analysis and alpha spectrometry. ^{226}Ra will be analyzed by the ^{222}Rn emanation technique and ^{228}Ra by radiochemical separation and low level beta counting or by ingrowth of ^{228}Th and alpha spectrometric analysis.

These analyses may be supplemented by or replaced by laboratory analyses of samples for ^{214}Bi and ^{228}Ac by high resolution gamma spectrometry using GeLi detectors.

5.1.3 Emanating Properties of Slag

The emanating properties of slag will be measured in order to characterize the rates of release of radon (^{222}Rn) and thoron (^{220}Rn).

5.1.3.1 Measurements. The following analysis of emanating properties will be performed for each of the six samples identified in section 5.1.2.4: Two equal portions of the sample will be taken. One will be left in bulk form, and the other will be ground to -100 mesh.

Each will be placed in a sealed container for one month, and the ingrowth and release of ^{220}Rn and ^{222}Rn to air trapped in the container will be measured over time by counting gross alpha in Lucas Flasks.

5.1.3.2 Results. The emanating power of the samples will then be inferred from these results, combined with the results of radiochemical measurements of ^{226}Ra and ^{228}Th in the same samples, both for bulk and pulverized slag.

5.1.4 Leachability of Slag

FeCb slag samples will be analyzed for leachability. One leachability study will be conducted using either ground water taken from wells #2 through #6, or water prepared in the lab to simulate water from these wells. The simulated well water will be used if the actual well water is found to contain trace contaminants of the substances being measured for leachability because such contamination would affect the outcome of the leachability tests. Wells #2 though #6 are located along the western boundary of the site, between the pond area and Chartier's Creek. The protocols for the leachability studies will be based upon the EPA TCLP parameters and the American Nuclear Society Standard for measurement of the leachability of solidified low-level radioactive wastes (ANSI standard ANSI/ANS-16.1-1986). The results will be used to model release rates to ground water for slag buried in bulk. At least one other leachability study will be performed, using one of the following leaching solutions: humic acids, distilled water, or simulated lung fluid.

Simulated lung fluid will be used in this second leachability study if in vivo leaching rates for inhaled insoluble material proves to be a significant pathway for dose assessment. Otherwise, humic acid or distilled water will be used to help model ground water transport rates.

5.1.5 Physical Properties of Slag.

The site characterization report will contain a description of the macroscopic physical properties of the FeCb slag, including color, density, appearance, friability, brittleness, and particle size.

5.2 Design of Survey for External Radiation and Contamination

Because natural Th is the major radioactive contaminant on-site at the Molycorp facility, and since bulk contamination by natural Th at levels exceeding the NRC option 1 guidance of 5 pCi/g is readily detectable by measurements of external gamma, the external radiation from surface and subsurface soils at the site can be completely characterized by gamma measurements. Therefore, on-site measurements of external radiation will be confined to gamma.

5.2.1 Surface Gamma Survey

Due to the significant amount of external gamma data already available for the Molycorp site, it is now possible to divide the site, at least in a general way, into affected and unaffected areas. (See Figure 5-2)The known affected areas are (1) the pond area extending from the west side of the Lanthanide Building to Chartier's Creek, on the west side of the site; (2) the storage yard in the northwest corner of the site; (3) the fenced area south of Caldwell Avenue (where the slag pile is located); and (4) spotty contamination along the north fenceline. Due to historical usage patterns, there is a potential for contamination under or adjacent to the R & D offices and the process buildings west of Building 34, where the FeCb slag was produced. The remainder of the property is thought to be unaffected.

An external gamma survey of the pond area was completed as part of the 1990 RSA survey at the site. As part of the site characterization study, this survey will be extended to cover all known affected or potentially affected areas. The survey will be made on a 20 foot grid system and will employ the procedures described in the 1990 RSA report. The grid system will coincide with the Cartesian co-ordinate system imposed on the site during the 1990 RSA survey. (English units were chosen instead of metric units for the grid, because the site is laid out in English units, making it easier and less costly to work in English system units.)

The survey will be conducted with scintillometers that have been cross calibrated against a pressurized ionization chamber. The values indicated by the scintillometers will be multiplied by the calibration constant obtained from the PIC, to yield true gamma. The true gamma values will be entered onto site maps. (See the 1990 RSA report for a detailed description of the calibration and survey techniques that will be employed.) The survey will also adhere to the guidance in NUREG/CR-

5849 on conducting open land surveys, recognizing, of course, that document is directed toward final site surveys, so that its recommendations are not always applicable to site characterization surveys.

The results of the external gamma survey is useful both for quantifying the external gamma rates and the concentrations of Th in surface soils. For example, 5 pCi/g of ^{232}Th (in equilibrium with its daughters) distributed uniformly in soil will produce a surface exposure rate of 14 μR/hr. Therefore, for example a surface gamma exposure rate below 23 μR/hr (14 μR/hr + natural gamma background of about 6 to 9 μR/hr in the vicinity of the Molycorp site) will indicate that the surface soils within a radius of about 10 meters of the measurement are below the NRC option 1 clean-up criteria.

In addition, field measurements may be made using a high resolution intrinsic Ge detector and multichannel analyzer, such as the ORTEC NOMAD system. This equipment permits the identification of the natural emitters present and the results can be interpreted in terms of the concentration of the ^{232}Th series in equilibrium in the soil. A sensitivity of 1pCi/g average for contaminated soil can be obtained with reasonable counting times with a sufficiently large detector.

A "walking survey," using scintillometers, will be made of the areas presently classified as unaffected. This survey will employ a lower density of measurements than that used for affected areas, and readings will not be recorded below 20 μR/hr. If any elevated gamma readings are detected, the area will be surveyed locally by surface survey with an intensity of effort equivalent to that in the affected area survey.

5.2.2 Subsurface Survey

The 1990 RSA survey of the site included subsurface measurements in 36 boreholes located in the pond area and in the yard in the northwest corner of the property. For the site characterization study, up to 300 additional boreholes will be drilled to bedrock (i.e., auger refusal) and logged at six inch intervals using a NaI probe to measure the intensity of the subsurface gamma field. The NaI readings (counts per minute) will be used to calculate the exposure rate in the borehole and the average concentration of natural Th in the surrounding material. Profiles of the variation with depth of Th concentrations in each hole will be graphed. The procedures for drilling and logging the boreholes and for graphing the borehole profiles is detailed in the 1990 RSA report.

The locations of the boreholes will be chosen to achieve the following goals:

(1) Extend coverage to include all affected areas on site.

(2) Increase the density of boreholes over that employed in the 1990 RSA survey.

(3) Locate the edges of contamination. To achieve this goal, the borehole coverage will overlap and extend into unaffected areas at boundaries between known affected and unaffected areas.

(4) Provide quantitative data to assess average downhole ^{232}Th activity vs. depth which can be used for the dose assessment , particularly for external exposure.

The data obtained by the drilling program will be useful for inventory of the amount and distribution of subsurface radioactivity, to better delineate affected and unaffected areas, and to provide information for a dose assessment.

The NRC in a memorandum dated Oct. 29, 1992 has accepted the utility of the downhole technique but requires more information in order to judge whether they will accept the quantitative interpretation in terms of average concentration of ^{232}Th at various depths. A separate report will be filed with the NRC within 2 weeks of submission of this SC plan, documenting the utility of the downhole calibration and interpretation of count rate as representing an average content of ^{232}Th. The alpha spectrometric data from the downhole samples will be presented in this report. The utility of this quantitative measurement for dose assessment purposes will be addressed. The extent of the underground monitoring program which will be undertaken depends upon whether or not the NRC will accept a quantitative interpretation of average ^{232}Th concentration from the gamma log data.

The locations of all boreholes will be surveyed and depicted on site maps drawn to scale. In addition, the locations will be reported in terms of the Cartesian co-ordinate system imposed on the site for the external gamma surface survey described in section 5.2.1.

5.2.3 Soil Analysis

About 200 soil samples will be taken from the surface in cores with a known area and to a known depth. Each sample will be screened and each fraction ground in a hammermill until homogeneous and an aliquot of each fraction will be analyzed by ICP. This method measures Th by mass and is readily capable of measuring 1 pCi/g of ^{232}Th (i.e., about 9 ppm). These samples may also or alternatively be analyzed by gamma and/or alpha spectrometry. The total sample contributes to external gamma exposure whereas only the smaller particle size fraction can be resuspended by wind and other disturbances and contribute to possible inhalation.

About 40 samples will be taken down boreholes and measured by the methods described in section 5.1 as a confirmation of the gamma survey results in the affected areas. It is not expected that the surface soil samples will produce a one to one correspondence with the results of gamma measurements made at the same location. The results from measurements of soil samples, by their very nature, are averages over small volumes whereas gamma measurements in free air result from the average emission rate of gamma rays over much larger volumes of soil; However the gamma ray exposure rates are much less sensitive to variations in homogeneity of the source distribution than are soil samples. At a site such as the Molycorp facility, where contamination is very spotty, highly variable, and not well mixed, one must expect a lot of "scatter" when comparing the results from a single sample to gamma measurements. The characterization of the site used to justify the decommissioning plan will rely heavily on gamma data, since that data is the result of direct measurement of much larger quantities of material than is possible from the use of soil sampling alone. The average produced by a gamma measurement is also a better indicator of exposure or dose than is that from a single soil sample. In addition the critical path for exposure from this site is probably external gamma exposure.

5.3 Surface Water and Sediments

5.3.1 Chartier's Creek Water Samples

The site characterization study will include upstream and downstream grab sampling. The upstream location will be in an area unaffected by site activities to establish background surface water quality. Samples will be taken from the stream bank in a well mixed zone. The downstream location will be north of the north property line in order to assess possible impact from all contributing areas of the plant site. If practical, the downstream location will be on the east bank, since the affected areas are all east of Chartier's Creek. Water levels will be recorded at the time samples are taken. Flow rates and volumes will be sufficiently characterized at both sampling locations to establish the relationship between water level and the volume and flow rate of the creek. Samples will be taken monthly for 6 months.

Samples with volumes one liter or larger will be filtered and non-filterable and filterable fractions will be analyzed for $^{228, 230, 232}Th$, ^{228}Ra, and ^{226}Ra. This information will provide a measure of effective rate of input of radionuclides from the ground water percolating through the site and into Chartier's Creek and may be used in the dose assessment in lieu of or in addition to results from the materials leaching studies.

5.3.2 Chartier's Creek Sediments.

One round of sediment sampling will be conducted at both the upstream and downstream locations. The samples will be analyzed using Inductively Coupled Plasma analysis (ICP) for Th. If the results exceed 10 ppm, the samples will also be analyzed by alpha or gamma spectrometry. In addition, the site characterization study will include a scan of creek banks and exposed sediments for elevated gamma, using a scintillometer. If readings are found in excess of 20 μR/hr, local soil samples will be collected and analyzed for Th using the ICP; if samples are found to exceed 40 ppm, they will be analyzed also by alpha spectrometry for Th isotopes.

5.3.3 Runoff from Affected Areas into Chartier's Creek

The topography of the affected areas will be studied to determine if any runoff from the affected areas discharges directly into Chartier's Creek. In the event that such discharges are present, one round of water sampling will be conducted during a discharge event. One sample will be collected at the outfall point, one immediately upstream, and one immediately downstream. The samples will be analyzed in the manner described in section 5.3.1

5.4 Soils in Vadose Zones

The vertical borehole study described in section 5.2.2 will include soils in the vadose zone. The depth at which any increase above background occurs will be available from the radiation logs of the boreholes. Studies have already been conducted that establish the relative gamma attenuation between saturated and non-saturated soils (see the 1990 RSA report). The gamma count rates from the vadose zone will be corrected to account for non-saturated conditions. Since the water table is very near the surface at this site, the vadose zone is very narrow.

Soil samples from two boreholes are currently being analyzed for ^{232}Th in order to verify the calibration established from first principles relating concentration of Th in the soil to counts per minute measured with the NaI probe in the boreholes. Based on these results more

, direct analyses of soil may or may not be needed. If needed, about 20 more soil samples will be taken from borehole cores with Th content in the range of 1 to 50 pCi/g and analyzed for ^{232}Th. This should assist in providing an appropriate calibration factor relating ^{232}Th content to gamma cpm, at concentrations of ^{232}Th producing gamma exposure comparable to background exposure rates.

Three boreholes in non-FeCb slag and 6 boreholes in adjacent soils not contaminated by site operations will be logged using the NaI probe in order to establish the background count rate due to gamma exposure from naturally occurring radionuclides in native soils and in other fill material used on site.

5.5 Groundwater

Twenty-one wells have been drilled from which groundwater samples can and have been taken. The ^{232}Th contained in slag buried on site is believed to be in an insoluble form, unavailable for leaching. ^{228}Th is similarly unavailable but, if any ^{228}Ra is present, the ^{228}Th daughter should be detectable. Historical information from the site on gross alpha, Th and other radionuclides previously measured in well water will be reviewed. About 20 samples of water from wells W2 through W6 will be analyzed using high sensitivity techniques for ^{232,230,228}Th, ^{238,234}U, and ^{226}Ra and ^{228}Ra, with detection limits for the U and Th isotopes of about 0.02 pCi/sample, for 1 liter sample sizes.

5.6 Buildings and Equipment

5.6.1 Structures and Fixed Equipment

All structures that have historically been used for the FeCb plant process or as storage areas for FeCb slag and Cb ore will be mapped on a CAD program. A scintillometer survey, with a density of approximately 1 reading per 100 ft^2 floor space will be made of each building. For buildings with areas of elevated gamma readings, walls, floors, and surfaces of fixed machinery will be scanned with alpha survey meters and maps and diagrams will be made showing the extent of contamination. Swipes moistened with alcohol will be taken and measured for gross alpha to determine the amount of removable activity. A sufficient number of measurements will be made to decide whether individual building and equipment will require decontamination as per the standards in Reg. Guide 1.86. See Figure 5-3 for a map depicting potentially contaminated buildings.

5.6.2 Vehicles and Mobile Equipment

For mobile equipment that has been historically used in a manner that might lead to contamination, surfaces will be scanned with a large area probe such as a gas proportional counter. Alcohol swipes will be taken and measured for gross alpha to determine the amount of removable activity.

5.6.3 Measurement of Th Under Existing Structures.

Bore holes will be drilled to permit NaI measurement of gamma radiation underneath buildings for which historical usage patterns suggest a potential for Th contamination of soils. The drilling program will involve penetration through floors, slant drilling or other drilling methods that will be developed in consultation with a drilling contractor. The holes will be logged and profiles of the variation with depth of Th concentration will be graphed, using the procedures employed for all other boreholes drilled on-site.

5.7 Air Sampling

5.7.1 Air samples:

Four air sampling locations will be established: one off-site and predominantly upwind of the affected areas, one off-site and downwind, one downwind at the site boundary , and one on-site near the ponds. Each sampler will collect at least 30 m^3 of air per week. (approximately 10,000 ft^3). The location on the downwind boundary will be adjacent to Chartier's Creek. The samples will be collected with generally accepted sampling equipment and procedures. This will permit the detection in air of 1% of the current 10CFR20 limits for Th in air.

5.7.2 Analysis

The filters from the air sampling program will be analyzed for Th isotopes by alpha spectrometry with a detection limit of 0.03 pCi/sample for ^{232}Th .

5.7.3 Concentration of Thorium

Airborne Th originating from on-site sources can be distinguished from that originating off-site because any concentration of Th from the site will have a different ^{230}Th/^{232}Th ratio than that from the natural local environment. See Figure 5-1, which shows that the ^{230}Th/^{232}Th ratio from slag is 0.1 whereas in normal soils adjacent to the plant, this ratio is 1:1. Based on the 1985 ORAU report which measured U and Th series in soil samples by gamma spectrometry the average ratio of ^{232}Th/^{226}Ra in 55 soil samples which exceeded a concentration of 10 pCi/g was 0.22. Therefore, any substantial additions of windblown Th isotopes from the site will be inferable from the Th isotope ratio measured in the air samples. The ^{232}Th/^{230}Th ratio measured in background soils was close to one.

5.7.4 Background

The background concentration of airborne Th will be measured at the upwind sampling location. However there can be significant variation in the background levels depending primarily upon the amount of dust in the atmosphere and its origin. Soil derived aerosol should exhibit an airborne $^{232}Th/^{230}Th$ ratio of about 1. and any significant addition to background derived from the site can be inferred by examining the disturbance in this ratio from one. The mass of aerosol collected will be weighed.

5.7.5 Sampling Intervals:

Weekly air samples will be collected, producing 104 samples over the first 6 months. After the first month, samples for each month will be composited and analyzed for monthly averages. Due to time limitations for completion of the site characterization study, a year's worth of data will not be available for inclusion in the SCR.

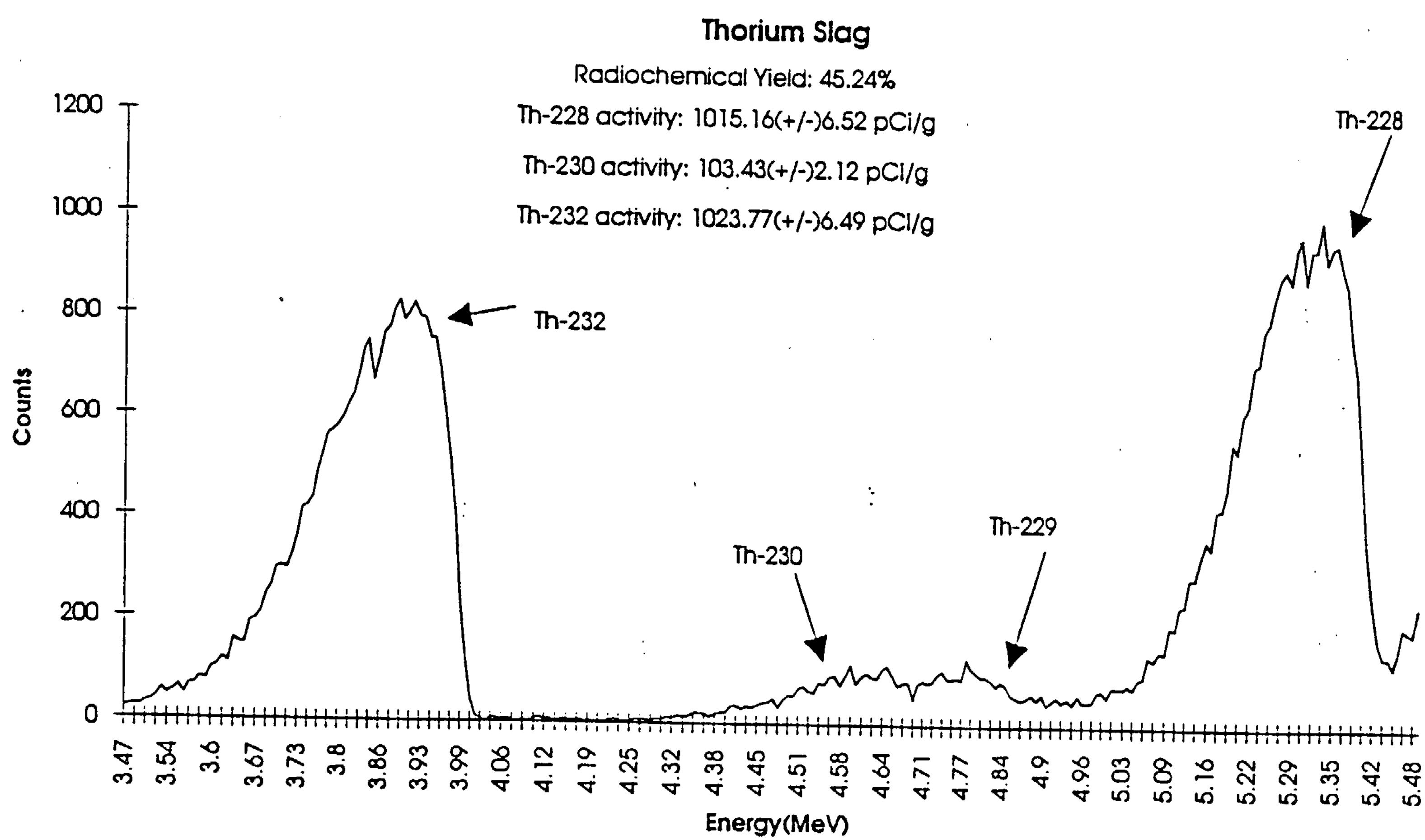

Figure 5-1

RSA, 11/5/92

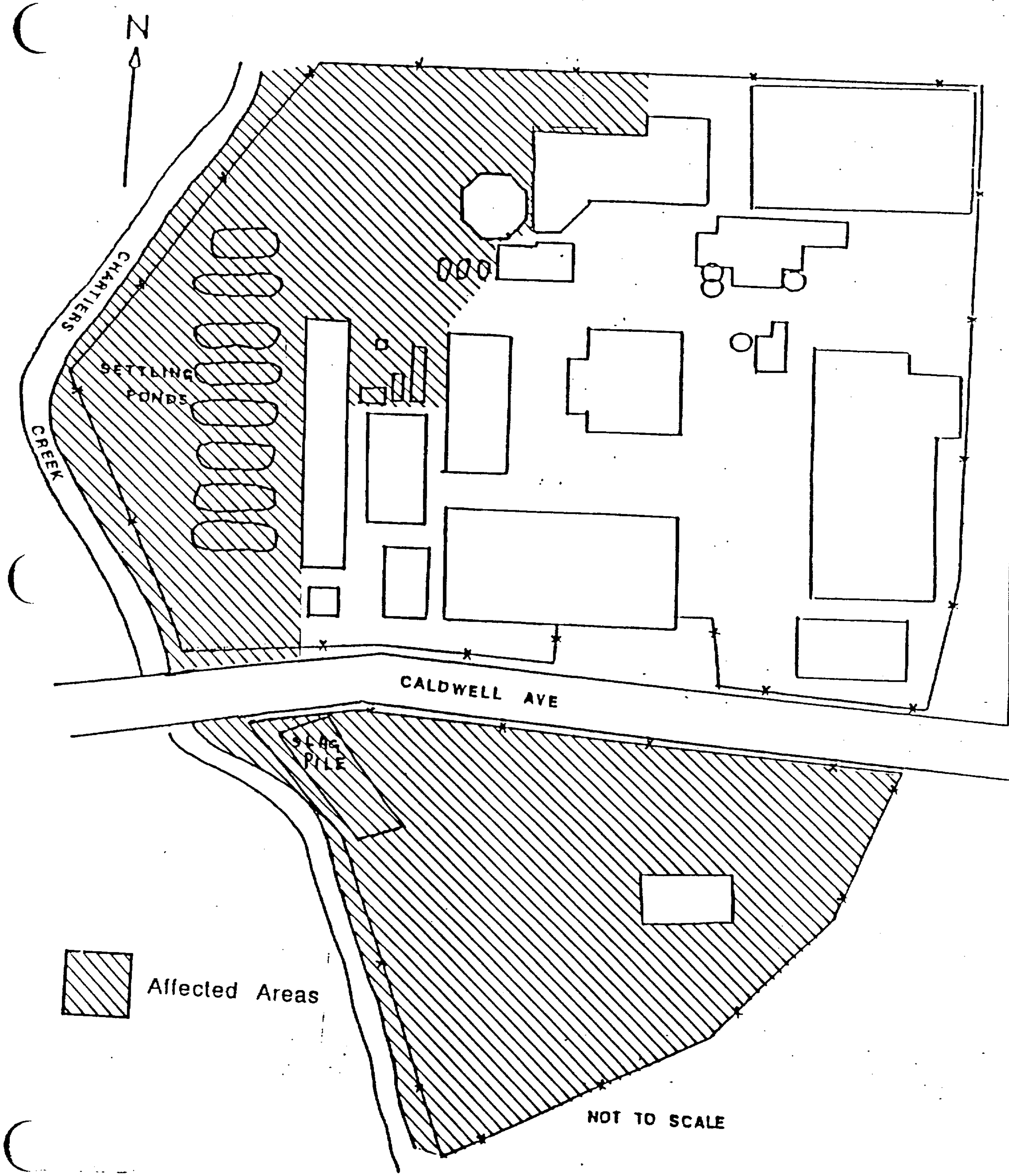

Figure 5-2: Areas at the Molycorp, Washington PA plant site currently classified as "affected areas."

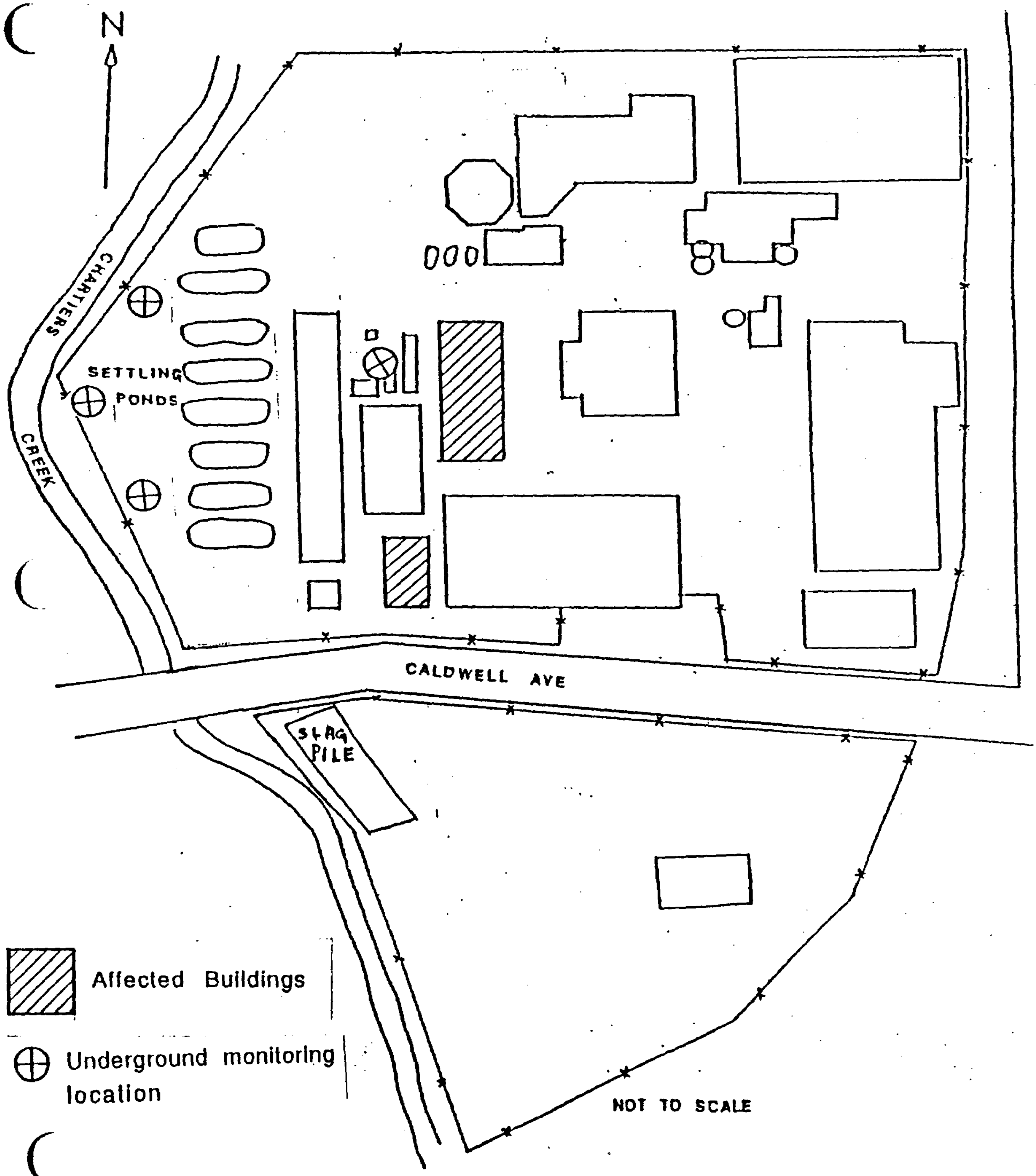

Figure 5-3: Buildings at the Molycorp, Washington PA plant site which, due to historic usage patterns, may be classified as "affected buildings."

Appendix A: Capabilities of the RESRAD program

The objective of this text is: (a) to provide a brief explanation about the necessary program inputs in order to match with the available data and to provide information on the necessity of new data acquisition. (b) to describe the outputs in order to allow the evaluation of the impacts due to the several pathways (individually and summed) and to provide possible site-specific remedial actions.

The RESRAD program deals with:

1) Concentration in soil
2) Concentrations of airborne radon decay products
3) Levels of external gamma radiation
4) Levels of radioactivity from surface contamination
5) Concentrations of radionuclides in air and water

Controlling Principles:

1) Annual radiation dose received by a member of critical group (realistic but conservative, for 50 years, not exceeding 100 mrem/y)
2) Doses should follow the ALARA principle

Pathway analysis:

1) Source analysis: (source terms: the rate at which residual radioactivity is released into the environment)
2) Environmental Transport Analysis:(identify environmental pathways by which radionuclides can migrate from the source to a human exposure location and determining the rate of migration)
3) Dose/exposure analysis: (dose conversion factors)
4) Scenario analysis: addresses problems of determining the quantity of radionuclides or radiation to which an individual is exposed.

Input data:

The input data needed by RESRAD are accessible in a series of input forms, which are briefly described as follows:

1) TITLE, USED DATA FILES, AND CONTAMINATED ZONE PARAMETERS:

a) AREA OF CONTAMINATED ZONE (m^2): Contains the locations of all soil samples with radionuclide concentrations that are clearly above background (if they exceed the background by at least two standard deviations) and are separated from the locations of other above-background soil samples by a distance of at least 100 m.
b) THICKNESS OF CONTAMINATED ZONE (m): the distance between the uppermost and lowermost soil samples with radionuclide concentrations that are clearly above background.
c) LENGTH PARALLEL TO AQUIFER FLOW (m): the distance between two parallel lines perpendicular to the direction of aquifer flow, one at the upgradient edge of the contaminated zone and the other at the downgradient edge. d) BASIC RADIATION DOSE LIMIT (mrem/year): the annual radiation dose limit used to derive all site-specific soil guidelines.
e) TIMES FOR CALCULATIONS (years): the times following the radiological survey for which the single radionuclide soil guidelines and mixture sums will be calculated. (Guidelines require that the mixture sum be less than one at all times).

2) INITIAL CONCENTRATIONS OF PRINCIPAL RADIONUCLIDES:

These important definitions were directly extracted from the RESRAD manual, since they are helpful in guiding the acquisition of data which will be used in the program:

"A principal radionuclide is defined as a radionuclide with a half-life longer than one year. An associated radionuclide is a decay product with a half-life of one year or less. The radionuclides "associated" with a principal radionuclide consist of all decay products down to, but not including, the next principal radionuclide in the chain. It is assumed that all associated radionuclides are in secular equilibrium with their principal radionuclide in the contaminated zone and also at the location of human exposure."

"If the contaminated zone is treated as an inhomogeneous contaminated zone, then the contaminated zone may be divided into subzones within each of which the peak concentration does not exceed the average concentration by a factor larger than three. The mixture sums for these subzones are then calculated as if each subzone were an isolated, homogeneous contaminated zone. The total of the mixture sums for subzones within a 100-m^2 area must be less than 1 for any 100-m^2 area within the contaminated zone. The current version of RESRAD will calculate the mixture sum only for a single homogeneous zone or subzone. For an inhomogeneous contaminated zone, the subzone contributions must be summed separately according to the procedures described in the Section 3.3 of the manual".

All radionuclides for which guidelines can be derived are listed and the corresponding nonzero concentrations in pCi/g can be entered.

3) COVER AND CONTAMINATED ZONE HYDROLOGICAL DATA:

More comprehensive definitions about the following parameters are given in the Appendix E of the manual.

a) COVER DEPTH (m): the distance from ground surface to the location of the uppermost soil sample with radionuclide concentrations that are clearly above background.

b) DENSITY OF COVER MATERIAL (g/cm^3): the bulk density of dry soil.

c) COVER EROSION RATE (m/year): rate at which soil is removed by erosion

d) DENSITY OF CONTAMINATED ZONE (g/cm^3): same as b)

e) CONTAMINATED ZONE EROSION RATE (m/year): same as c)

f) CONTAMINATED ZONE TOTAL POROSITY: g) CONTAMINATED ZONE EFFECTIVE POROSITY:

h) CONTAMINATED ZONE HYDRAULIC CONDUCTIVITY (m/year):

i) CONTAMINATED ZONE b PARAMETER:

j) EVAPOTRANSPIRATION COEFFICIENT:

k) PRECIPITATION (m/year):

l) IRRIGATION (m/year):

m) IRRIGATION MODE (0 FOR OVERHEAD; 1 FOR DITCH):

n) RUNOFF COEFFICIENT:

o) WATERSHED AREA FOR NEARBY STREAM OR POND (m^2):

Default values for items b) to o) are provided in the program to allow preliminary estimates. Typical parameter values for various soil materials are presented in the Appendix E.

4) SATURATED ZONE HYDROLOGICAL DATA:

Definitions about the following parameters are given in the Appendix E of the manual.

a)DENSITY OF SATURATED ZONE (g/cm^3):

b) SATURATED ZONE TOTAL POROSITY:

c) SATURATED ZONE EFFECTIVE POROSITY:

d) SATURATED ZONE HYDRAULIC CONDUCTIVITY (m/year):

e) SATURATED ZONE HYDRAULIC GRADIENT:

f) SATURATED ZONE b PARAMETER: (only if h) > 0)

g) DISTANCE FROM SURFACE TO WATER TABLE (m): = Cover Depth + Contaminated Zone Thickness + Thicknesses of the unsaturated zone strata below the contaminated zone.

h) WATER TABLE DROP RATE (m/year): rate that the depth of the water table decreases. If it is not zero, the unsaturated zone thickness will be created or increased.

i) WELL PUMP INTAKE DEPTH (m below water table):

j) NONDISPERSION OR MASS-BALANCE: selects which of the two models will be used for water/soil concentration ratio calculations

k) INDIVIDUAL'S USE GROUNDWATER (m^3/year):

Default values for all items are provided in the program to allow preliminary estimates. Typical parameter values for various soil materials and radionuclides are presented in the Appendix E.

5) UNCONTAMINATED AND UNSATURATED ZONE HYDROLOGICAL DATA:

The uncontaminated and unsaturated zone is the portion of the uncontaminated zone that lies below the bottom of the contaminated zone and above the groundwater table. The program has provisions for up to five different horizontal strata within this zone. Each stratum is characterized by six radionuclide- independent parameters:

a) THICKNESS (m):

b) SOIL DENSITY (g/cm^3):

c) TOTAL POROSITY:

d) EFFECTIVE POROSITY:

e) SOIL-SPECIFIC b PARAMETER:

f) HYDRAULIC CONDUCTIVITY (m/year):

Default values for all items are provided in the program to allow preliminary estimates. Typical parameter values for various soil materials and radionuclides are presented in the Appendix E.

6) DISTRIBUTION COEFFICIENTS (cm^3/g) AND LEACH RATES ($year^{-1}$):

If the radionuclide leach rates in the contaminated zone are known, these leach rates should be entered. If a leach rate is entered (>0), it will be used to calculate the leaching of radionuclides from the contaminated zone. If a leach rate is not entered (=0), the program will calculate the leach rate using the distribution coefficient for the contaminated zone. In addition to the on-site principal radionuclides, it allows parameters to be entered for decay product principal radionuclides. Default distribution coefficients are provided by the program for most radionuclides. The manual also remarks that these values should be used with care because site-specific distribution coefficients can vary over many orders of magnitude depending on the soil type, pH, redox potential and presence of other ions. Replacement with site-specific values is recommended.

Default values for all items are provided in the program to allow preliminary estimates. Typical parameter values for various soil materials and radionuclides are presented in the Appendix E.

7) EXTERNAL GAMMA AND DUST INHALATION PARAMETERS:

a) INHALATION RATE (m^3/year): default=8400
b) MASS LOADING FOR INHALATION (g/m^3): default=0.0002
c) OCCUPANCY AND SHIELDING FACTOR (EXTERNAL GAMMA): default=0.6
d) OCCUPANCY FACTOR (INHALATION): default=0.45
e) SHAPE FACTOR (EXTERNAL GAMMA): default=1
f) HEIGHT OF MIXING FOR AIRBORNE DUST (INHALATION)(m): default=3

These values are not strongly site-dependent, in most circumstances the generic default values can be used.

8) INGESTION PATHWAY DATA, DIETARY PARAMETERS

a)FRUITS, VEGETABLES AND GRAIN CONSUMPTION (kg/year):default=160

b) LEAFY VEGETABLE CONSUMPTION (kg/year): default=14
c) MILK CONSUMPTION (l/year): default=92
d) MEAT AND POULTRY CONSUMPTION (kg/year): default=63
e) FISH CONSUMPTION (kg/year): default=5.4
f) OTHER AQUATIC FOOD CONSUMPTION (kg/year): default=0.9
g) DRINKING WATER INTAKE (l/year): default=410
h) FRACTION OF DRINKING WATER FROM SITE (0-1): default=1
i) FRACTION OF AQUATIC FOODS FROM SITE (0-1): default=0.5

The default parameter values have been chosen to correspond to national averages. The parameters, other than h) and i), are not strongly site dependent. The parameters h) and i) allow specification of the fraction of contaminated intake for these pathways.

9) INGESTION PATHWAY DATA, NONDIETARY PARAMETERS

a)LIVESTOCK FODDER INTAKE FOR MEAT (kg/day):default=68
b)LIVESTOCK FODDER INTAKE FOR MILK (kg/day):default=55
c)LIVESTOCK WATER INTAKE FOR MEAT (l/day):default=50
d)LIVESTOCK WATER INTAKE FOR MILK (l/day):default=160
e) MASS LOADING FOR FOLIAR DEPOSITION (g/m^3): default=0.0001
f) DEPTH OF SOIL MIXING LAYER (m): default=0.15
g) DEPTH OF ROOTS (m): default=0.9

GROUNDWATER FRACTIONAL USAGE (BALANCE FROM SURFACE WATER)
h) DRINKING WATER (0-1): default=1
i) LIVESTOCK WATER (0-1): default=1
j) IRRIGATION (0-1): default=1

The default parameter values have been chosen to correspond to national averages. The parameters, other than h), i) and j), are not strongly site dependent. The final three parameters are included to allow groundwater (well) and surface water (pond) scenarios. Hence, the fractions will usually be set at 1 or 0. For livestock water and irrigation all usage is assumed to be from the site. The fraction of contaminated drinking water (from the site) can be varied via the parameter h) of item 8) INGESTION PATHWAY DATA, DIETARY PARAMETERS.

Control of RESRAD Pathways:

RESRAD always computes the radiation dose resulting from seven potential pathways:
1) Direct exposure to external radiation from contaminated soil material.
2) Internal radiation from inhalation.
3) Internal radiation from ingestion of plant foods grown on-site and irrigated with water drawn from an on-site well or pond.
4)Internal radiation from ingestion of meat from livestock fed with fodder grown on-site and water drawn from an on-site well or pond.
5)Internal radiation from ingestion of milk from livestock fed with fodder grown on-site and water drawn from an on-site well or pond.
6) Internal radiation from ingestion of aquatic foods from an on- site pond.
7)Internal radiation from drinking water from an on-site well or pond.

Since in many situations certain of these pathways are not important, the program allows the user to suppress one or more pathways.

RESRAD Outputs:

A summary report (SUMMARY.REP) and a detailed report (DETAILED.REP) are generated. Total dose and the total mixture sum for the various selected times are estimated. The total mixture sum is the estimated effective dose equivalent, expressed as a multiple of the basic dose limit, that a member of the critical population group might receive at time t following the radiological survey as a consequence of the residual radioactivity. A site may be certified in compliance with guidelines only if the mixture sum does not exceed the value of one at any time within the time horizon.

Total dose components for all individual pathways at different times are also presented as actual dose (mrem/y) and percent contribution to the total.

The summary report also presents results for:
- Total dose/source (mrem/yr)/(pCi/g) summed over all pathways for radionuclide i and time t.
- Single-radionuclide soil guidelines (pCi/g) for radionuclide i and time t.
- The results above for values of t which equals the minimum soil guidelines and values of t for the maximum total dose.

The single-radionuclide soil guidelines are the concentration guidelines that would apply if only one radionuclide were present. A single-radionuclide soil guideline is the magnitude of the initial concentration of the i^{th} principal radionuclide that would result in a potential radiation dose equal to the basic radiation limit to a member of the critical population group at time t.

The detailed report allows to verify the code and can be useful for gaining insight into the transport mechanisms by enabling a more detailed investigation of the effect of parameter changes on pathway factors, environmental transport factors, and dose/source ratios for different pathways.

Appendix B: Current and Proposed Concentration Limits for Insoluble Th in Air (General Public)

ISOTOPE	NEW PART 20 (Effective 1/1/94, µCi/ml)	CURRENT PART 20 (µCi/ml)	CURRENT/NEW
Nat Th	N/A	2×10^{-12}	---
^{232}Th	6×10^{-15}	1×10^{-12}	166
^{228}Th	2×10^{-14}	2×10^{-13}	10
^{230}Th	3×10^{-14}	3×10^{-13}	10

ISOTOPE	NEW PART 20 (Effective 1/1/94, pCi/m^3)	CURRENT PART 20 (pCi/m^3)
Nat Th	N/A	2
^{232}Th	0.006	1
^{228}Th	0.02	0.2
^{230}Th	0.03	0.3

NOTES:

NEW PART 20: PART VI

Nuclear Regulatory Commission
10 CFR Part 20 et al.
Standards for Protection Against Radiation; Final Rule
Tuesday May 21, 1991.

EXTRACTED FROM: Appendix B to par. 20.1001-20.2401 - Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage.

CURRENT PART 20: UNITED STATES NUCLEAR REGULATORY COMMISSION
RULES AND REGULATIONS
TITLE 10, CHAPTER 1, CODE OF FEDERAL REGULATIONS- ENERGY
PART 20 STANDARDS FOR PROTECTION AGAINST RADIATION

EXTRACTED FROM: Appendix B - Concentrations in Air and Water Above Background

Appendix C: Radiochemical Techniques

Dissolution of Slag:

A known amount of slag (200-300 mg) ground to a small particle size to facilitate dissolution is transferred into a Teflon beaker. Known amounts of ^{229}Th and ^{232}U isotopic tracers are added to the sample directly into the Teflon beakers. Approximately 15-20 ml of concentrated HNO_3 and 5 ml of HF are added to the Teflon beaker containing the slag. The beaker is heated strongly. The process is repeated several times until there is no insoluble material left. The solution is evaporated to dryness, and the residue is redissolved in concentrated HNO_3. The process is repeated two to three times to remove the traces of HF.

Radiochemical Determination of Uranium and Thorium Isotopes:

Uranium and thorium isotopes are determined in the slag samples by radiochemical procedures developed by Singh et al as described below:

a) Co-precipitation of Uranium and Thorium:

Uranium and thorium are co-precipitated with the iron present in the slag sample by adding ammonium hydroxide to the solution obtained after the dissolution of the slag. The pH is adjusted to 10 and the solution is boiled for about 15 minutes. The precipitate is centrifuged, washed several times and dissolved in 10M HCl. The molarity of the solution is adjusted to 10M.

b) Solvent Extraction:

Uranium, present in the slag, is extracted into 20% tri-lauryl amine (TLA) solution in xylene pre-equilibrated with 10M HCl, leaving thorium in the aqueous solution. The organic phase (TLA phase) is washed two times with 10M HCl (by shaking the organic phase with equal volume of 10M HCl) and the washings are discarded. Finally, uranium present in the organic phase is back extracted with 0.1M HCl (by shaking the organic phase with equal volume of 0.1M HCl).

The aqueous phase containing thorium is evaporated to dryness, redissolved in 4MHNO_3 and the molarity adjusted to 4M. Thorium is extracted into 20% TLA solution in xylene pre-equilibrated with 4M HNO_3. The organic phase is washed twice with equal volume of 4M HNO_3 and the washings are discarded. Thorium is finally back extracted from the TLA phase by shaking with equal volume of 10M HCl.

c) Electrodeposition of Uranium and Thorium:

Uranium and thorium back extracted separately into 0.1M HCl and 10M HCl, respectively are evaporated to dryness, with addition of a few drops of HNO_3 and H_2O_2 to decompose the organic materials entrained with the acid. Sodium bisulphate solution in 2M H_2SO_4 (5ml) is added to each of the solution and heated strongly with occasional additions of HNO_3 and H_2O_2. The solution is evaporated to dryness and the residue is dissolved in 5 ml of 1M $(NH_4)_2$ SO_4 solution in water. The solution is transferred into the plating solutions and the pH is adjusted to ~2 by using thyomol blue as an indicator. Uranium and thorium are electrodeported separately onto the polished stainless steel or platinum disc by passing a constant current of 1.2 amperes for one hour.

Alpha-spectrometry:

The radiochemical yields of uranium and thorium tracer and their isotopic compositions in the sample, are determined by counting the discs in an alpha-spectrometer with a surface barrier silicon diode of 450 mm^2 active area, 100 micron sensitive thickness, and 30 KeV FWHM resolution, and a multichannel analyzer. The counter efficiencies are determined by counting a standard source electrodeposited on a platinum disc containing three isotopes of Pu (Pu-238, 239 and 242) and the backgrounds are determined by counting a blank disc.

Determination of Radium-226:

Radium-226 in solution is determined by de-emanating its ^{222}Rn progeny into an ionization chamber or scintillation cell for measurement. The ^{222}Rn can be de emanated by bubbling an inert gas through the solution either after equilibrium has been established or after any known time period. Two half-lives, 7.65 days, for example, give 75% of the maximum buildup. The chambers are standardized by de emanating aliquots of standard reference ^{226}Ra solution.

Bioassay Procedures for Uranium, Thorium and Radium:

a) Sample Collection:

Urine and fecal samples have been utilized to determine the daily excretions of radionuclides in order to be able to estimate the total body burden and/or current exposures to these radionuclides.

Urine samples are collected from individuals for a period of 24 hours. The subjects are provided with a 2 liter polyethylene bottle, a pair of gloves and a marking pen. The subjects are asked to wash their hands before collecting the samples. They should discard the first voiding of the early morning and thereafter, start collecting the urine samples in the polyethylene bottle provided to them. They should directly urinate in the same bottle the entire day and evening and also collect the first voiding of the next morning. The urine samples should either be stored in a refrigerator or transferred to the laboratory where 5% hydrochloric should be added immediately to preserve the samples.

Fecal samples are directly collected in a plastic bag which is kept attached to the commode of the bathroom. The tissue wipes should not be collected because the risk of losing the sample is much less as compared to the risk of contaminating the samples.

Techniques for measuring Uranium, Thorium and Radium in Urine and Feces:

Uranium and thorium in urine samples can be determined by the radiochemical procedure developed by Singh et al using alpha spectrometric techniques. The urine samples, spiked with ^{232}U and ^{229}Th tracer are wet ashed with HNO_3 with occasional additions of a few drops of HNO_3 and H_2O_2. Uranium and thorium are co precipitated with iron as hydroxide or with calcium as oxalate. Uranium and thorium are separated from the bulk of inorganic materials present in the sample and from each other by solvent extraction techniques described earlier. They are electrodeposited on a stainless stell or platinum disc. The samples are counted by alpha-spectrometry.

Other techniques are also available for the measurements of uranium and thorium in bioassay samples. Uranium may be determined by time-resolved laser-induced fluorescence. However, the technique does not give the isotopic composition of uranium. Similarly, thorium can be determined by neutron activation analysis and ICP techniques. However, these techniques are not capable of determining the isotopic composition of thorium.

Radium in bioassay samples can be determined by de-emenating its ^{222}Rn progeny as described earlier, once the samples are wet ashed and dissolved in appropriate acid and separated from the bulk of materials present in the samples.

Radiochemical Determinations of Ra-226 and Ra-228 in Water:

After sample preparation, ^{226}Ra is isolated from most other elements by co-precipitation with Barium Sulfate using ^{133}Ba as carrier. The sulphate precipitate is dissolved in alkaline EDTA to prepare the emanating solution. The chemical yield of barium is determined by measuring the g energy of ^{133}Ba. Radium is measured by de-emanating its ^{222}Rn progeny into an ionization chamber or scintillation cell. The ^{222}Rn can be de-emanated by bubbling an inert gas through the solution either after equilibrium has been established or after any known time period.

Radium-228 is a b emitter. The determination of Ra-228 in the presence of alpha emitting nuclides is difficult because of its weekly energetic b emission. However, Radium-228 decays into 6.13 hour actinium-228, and the procedure for Radium-228 analysis involves the separation and counting of actinium-228.

After preparing the solution, the solution is aged for at least 36 hours for actinium-228 ingrowth. Actinium is extracted into EHPA and extracted with 1.5M HBr. Lead and bismuth are extracted into aliquot 336 leaving actinium in the aqueous phase. Actinium is transferred onto the stainless planchette, dried, baked and counted.

Radium-228 may be determined by another procedure also. Thorium-228 present in the sample is quantitatively removed by extracting Th-228 in the TLA solution. The aqueous phase containing Ra-228 is stored for the ingrowth of Th-228, which may be then determined by the procedure given for thorium.

QA/QC Program:

The management of the RSA is fully committed to the maintenance of an effective quality control/assurance program in order that all work carried out by RSA will be of high quality. An important aspect of the RSA quality control/assurance program is the written documentation of quality assurance and quality control procedures that are used in the performance of projects. The most important requirement for the success of the quality control/assurance program is the commitment in the laboratory that our goal is to always perform high quality work.

Quality assurance involves all those planned and systemic actions necessary to provide adequate confidence that a facility, structure, system, or component will perform satisfactorily and safely in service.

Quality control, which is included within quality assurance, comprises all those actions necessary to control and verify the features and characteristics of a material process products; or service to specified requirements.

For every batch of ten samples, we run one reagent blank (for low level samples), one spiked sample (prepared by a person other than the analyst), and the reference materials obtained from NIST or EPA, for the determinations of isotopic uranium, thorium and radium. Peruvian soil (SRM 4355) obtained from NIST is used as a reference material for uranium and thorium and a standard source of ^{226}Ra obtained from EPA is used as the standard for radium determinations.

The alpha-spectrometers are calibrated with a standard source containing 3 alpha emitting isotopes with different energies electrodeposited onto a platinum disc, and energy calibration regularly. Backgrounds of the counters are determined by counting a blank disc over a period of 2 days. A record is maintained for the efficiency and the background for each detector.

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