DOE/OR/07-1586&D1

# Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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April 9, 1997

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**BACKGROUND LEVELS OF SELECTED RADIONUCLIDES AND METALS IN SOILS AND GEOLOGIC MEDIA AT THE PADUCAH GASEOUS DIFFUSION PLANT (PGDP), PADUCAH, KENTUCKY (DOE/OR/07-1586&D1)**

Dear Sirs:

Enclosed for your review is the subject document. Please provide any appropriate comments on this document by Friday, May 16, 1997, in order to maintain the scheduled submission of the revised D2 document by May 30, 1997.

If you have any questions or require additional information, please call Carlos R. Alvarado at (502) 441-6804.

Sincerely,

Jimmie C. Hodges, Site Manager
Paducah Site Office

EF-22:Alvarado

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## CERTIFICATION

**Document Identification:** **Background Levels of Selected Radionuclides and Metals in Soils and Geologic Media at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (DOE/OR/07-1586&D1)**

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this application and all attachments and that, based on my inquiry of those persons immediately responsible for obtaining the information contained in the application, I believe that the information is true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

U. S. Department of Energy
Owner and Operator

Jimmie C Hodges — 4-10-97

Jimmie C. Hodges, Paducah Site Manager — Date Signed
Paducah Site Office
U. S. Department of Energy

The Department of Energy has signed as "owner and operator" and Lockheed Martin Energy Systems, Inc., has signed as "co-operator" this application for the permitted facility. The Department has determined that dual signatures best reflect the actual apportionment of responsibility under which the Department's RCRA responsibilities are for policy, programmatic, funding, and scheduling decisions, as well as general oversight, and the contractor's RCRA responsibilities are for day-to-day operations (in accordance with general directions given by the Department of Energy as part of its general oversight responsibility), including but not limited to, the following responsibilities: waste analyses and handling, monitoring, record keeping, reporting, and contingency planning. For purposes of the certification required by 40 CFR Section 270.11(d), the Department of Energy's representatives certify, to the best of their knowledge and belief, the truth accuracy and completeness of the application for their respective areas of responsibility.

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Lockheed Martin Energy Systems, Inc.
Co-Operator

Jimmy C. Massey, Site Manager
Environmental Management and Enrichment Facilities
Lockheed Martin Energy Systems, Inc.

4/1-/97
Date Signed

The Department of Energy has signed as "owner and operator" and Lockheed Martin Energy Systems, Inc., has signed as "co-operator" this application for the permitted facility. The Department has determined that dual signatures best reflect the actual apportionment of responsibility under which the Department's RCRA responsibilities are for policy, programmatic, funding, and scheduling decisions, as well as general oversight, and the contractor's RCRA responsibilities are for day-to-day operations (in accordance with general directions given by the Department of Energy as part of its general oversight responsibility), including but not limited to, the following responsibilities: waste analyses and handling, monitoring, record keeping, reporting, and contingency planning. For purposes of the certification required by 40 CFR Section 270.11(d), Lockheed Martin Energy Systems, Inc.'s, representatives certify, to the best of their knowledge and belief, the truth accuracy and completeness of the application for their respective areas of responsibility.

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Environmental Management Activities at the
PADUCAH GASEOUS DIFFUSION PLANT
Paducah, Kentucky 42002
managed by
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# PREFACE

The purpose of this report is to present the efforts of the Background Soils Project for the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky. This project was developed to determine the background levels of selected metals and radionuclides in soils from uncontaminated areas in proximity to the PGDP. The work was performed under Work Breakdown Structure 1.4.12.7.1.02.22.

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# ACRONYMS

| | |
|---|---|
| ANOVA | analysis of variance |
| CLP | Contract Laboratory Program |
| DOE | U.S. Department of Energy |
| DQO | Data Quality Objective |
| EPA | U.S. Environmental Protection Agency |
| ER | Environmental Restoration (Program) |
| HU | hydrogeological unit |
| ICP-MS | Inductively-Coupled Plasma-Mass Spectroscopy |
| KyDEP | Kentucky Department for Environmental Protection |
| LAS | Lockheed Analytical Services |
| LMES | Lockheed Martin Energy Systems, Inc. |
| LTB | lower tolerance bound |
| MW | monitoring well |
| NRCS | Natural Resources Conservation Service |
| NAA | neutron activation analyses |
| PGDP | Paducah Gaseous Diffusion Plant |
| PRG | preliminary remediation goal |
| RGA | regional gravel aquifer |
| UTB | upper tolerance bound |

# EXECUTIVE SUMMARY

The purpose of this report is to document the efforts of the Background Soils Project for the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky. This project was started in 1996 to determine the background levels of selected metals and radionuclides in soils from uncontaminated areas in proximity to the PGDP. The A and B horizons of three dominant soils series of the PGDP were sampled from a 6- by 12-mile area west-northwest of the PGDP. Deep geologic media were sampled from the dominant hydrologic units immediately south and west adjacent to the PGDP. The decision to collect surface samples from this area was based primarily on the premise that this represented an area "up wind" from the PGDP, thereby reducing the possibility that these soils may have been contaminated due to local deposition of washout and dry-fallout of potential contaminants emanating from the PGDP.

Selection of surface soils was based on land use history, conformance with classification of soils similar to those at the PGDP, parent material, bedrock formation, geomorphology, and hydrology. Sampling of deep geologic media was centered on the collection of samples upgradient in the dominant hydrologic units and geologic formations ranging in depths from 3 to 30 ft immediately south and southwest of the PGDP in the Kentucky Wildlife Management area. The selected radionuclides included $^{137}Cs$, $^{237}Np$, $^{238}Pu$, $^{226}Ra$, $^{90}Sr$, $^{99}Tc$, $^{228}Th$, $^{230}Th$, $^{232}Th$, $^{234}U$, $^{235}U$, $^{238}U$, and $^{40}K$. The selected metals included Sb, Be, Cd, Tl, and total uranium. [Note, the background levels developed for the metals listed here supercedes the background levels for these metals developed by DOE (1996[1]). However, the background concentrations for any metal not listed here remain as those presented by DOE (1996[1]).]

Analyses performed as part of this project included $\alpha$, $\beta$, and $\gamma$ spectroscopy methods for radionuclides and Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) for metals and selected radionuclides ($^{232}Th$, $^{235}U$, and $^{238}U$). The contract laboratory conducting the analyses was required to use standard U.S. Environmental Protection Agency (EPA) methods. In addition to these chemical analyses, particle size determinations on the surface soil and hydrologic unit 1 (HU1) (loess) samples were made, and for comparative purposes, neutron activation analyses (NAA) were performed to determine concentrations of $^{232}Th$, $^{235}U$, and $^{238}U$. Measurements made in the laboratory and methods used to manage the data were established in equivalence to what was formerly termed EPA Level III with respect to quality assurance and quality control. Therefore, all data developed as part of this project are definitive data. No major data quality or data management concerns were encountered as part of this project.

All of the project's stated objectives were accomplished. These objectives included:

- determining background levels of selected radionuclides and metals in undisturbed soils providing a useable database for establishing clean-up levels of contaminants,
- developing a validated and defensible baseline database which could be used for contaminant assessment, and

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[1] *Background Concentrations and Human Health Risk-based Screening Criteria for Metals in Soil at the Paducah Gaseous Diffusion Plant, Paducah Kentucky*, DOE/OR/07-1417&D2.

- providing a database to evaluate risk from constituents in background soils for comparison with risk from contaminated sites.

The activities and concentrations of analytes measured in selected soil horizons and hydrologic units were expressed in a variety of statistical terms: the range, mean (with the upper and lower 95% confidence bounds), standard error of the mean, and the estimate for the 95%$^{th}$ percentile (with the upper and lower 95% tolerance bounds). Background concentrations for measured analytes in this study were set at their 95% upper tolerance bound (UTB) on the 95$^{th}$ percentile concentration. This statistical determination was used to delineate the upper boundary between a normal background distribution that might occur in soils to that encountered in a contaminated environment. In this framework, the UTB has been defined as the background level for that analyte. From this perspective, any analyte whose level is above its UTB can be confidently considered above background.

Risk evaluations were conducted using the UTBs measured in the A and B soil horizons from the three dominant soil series near the PGDP. For the radionuclide data, this included the analyses of 15 (12 plus 3 field duplicates) composite soil samples for each horizon (each composite sample contained soil from three equivalent soil sites of the same soil series); therefore, these analyses represented 36 soil sampling sites. Similar statistics apply to the metals data (total uranium included) for the A and B horizons; however, these statistics do not apply to antimony and cadmium in A horizon (where all samples collected were below the 0.021 mg/kg instrumental detection limit) and thallium in B horizon (where only 4 and 12 composite samples were above the detection limit). Background levels for the radionuclides and metals within the various soil horizons/hydrologic units are presented in Tables ES-1 and ES-2, respectively.

To develop a single list of background levels in surface soil and subsurface soil and determine if any background concentrations of metals and radionuclides in soil were markedly greater than risk-based screening criteria, a risk evaluation was completed of the background concentrations developed as part of the work (i.e., 95% UTB value discussed earlier) and those developed by DOE (1996[1]). In this evaluation, the various selected background concentrations were compared to risk-based concentrations for industrial and residential users and to state soil screening values. This evaluation showed that several metals' background concentrations were much higher than their residential use risk-based concentrations. These metals were Al, As, Be, Fe, Pb, Mn, and V. In addition, this evaluation showed that the selected background concentration of two radionuclides also markedly exceeds residential use risk-based values. These radionuclides were $^{40}$K and $^{226}$Ra. Results comparing the background concentrations to industrial use risk-based levels were similar.

The risk evaluation results indicate that the risk posed by the metals and radionuclides listed previously may make up a substantial portion of the background risk at PGDP. Therefore, the risk posed by these metals and radionuclides at their background concentrations should be considered when making remedial decisions and selecting clean-up levels for the PGDP.

Cs 137

**Table ES.1. Background levels of radionuclides in soils and deep geologic media in the vicinity of the PGDP[a]**

| Soil horizon/ hydrologic unit | Cs-137 | K-40 | Np-237 | Pu-238 | Pu-239 | Ra-226 | Sr-90 | Tc-99 | Th-228 | Th-230 | Th-232 | U-234 | U-235 | U-238 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (pCi/g) | | | | | | | | | | | | | |
| A | 0.494 | 16.031 | 0.102 | 0.073 | 0.025 | 1.481 | 4.719 | 2.535 | 1.582 | 1.452 | 1.476 | 2.485 | 0.144 | 1.221 |
| B | 0.283 | 16.248 | nm[b] | nm | nm | 1.518 | nm | 2.779 | 1.586 | 1.445 | 1.487 | 2.438 | 0.143 | 1.166 |
| Loess | 0.139 | 13.036 | nm | nm | nm | 1.089 | nm | 0.496 | 1.180 | 1.217 | 1.225 | 1.040 | 0.128 | 0.921 |
| HU-2 | 0.140 | 6.431 | nm | nm | nm | 1.050 | nm | 0.496 | 1.061 | 0.882 | 1.078 | 0.953 | 0.117 | 0.977 |
| HU-3 | 0.143 | 5.256 | nm | nm | nm | 1.150 | nm | 0.548 | 1.396 | 1.053 | 1.326 | 1.182 | 0.112 | 1.009 |
| Eoc. Sand | 0.147 | 2.451 | nm | nm | nm | 0.570 | nm | 0.521 | 0.541 | 0.374 | 0.577 | 0.492 | 0.092 | 0.401 |
| PC Clay | 0.141 | 9.501 | nm | nm | nm | 1.213 | nm | 0.634 | 1.393 | 1.153 | 1.422 | 1.429 | 0.167 | 1.288 |

[a]Background levels are defined as the upper tolerance bound of the 95 percentile. For risk analyses, the background level from A horizon is to be used for surface soil (i.e., 0 to 1 foot below ground surface), and the background level from B horizon is to be used for subsurface soil (i.e., more than 1 foot below ground surface).
[b]Not measured in subsurface horizons.

**Table ES.2. Background levels of metals in soils and deep geologic media in the vicinity of the PGDP[a]**

| Soil horizon/ hydrologic unit | Beryllium | Thallium | Total uranium |
|---|---|---|---|
| | (mg/kg) | | |
| A | 0.673 | 0.209 | 4.853 |
| B | 0.686 | 0.336 | 4.637 |
| Loess | 0.604 | 0.216 | 3.663 |
| HU-2 | 0.504 | bd[b] | 3.883 |
| HU-3 | 0.747 | 0.255 | 4.012 |
| Eoc. Sand | bd | bd | 1.595 |
| PC Clay | 1.282 | 0.542 | 5.122 |

[a]Background levels are defined as the upper tolerance bound of the 95 percentile. For risk analyses, the background level from A horizon is to be used for surface soil (i.e., 0 to 1 foot below ground surface), and the background level from B horizon is to be used for subsurface soil (i.e., more than 1 foot below ground surface). In addition, in risk analyses, the maximum detection limit used for antimony and cadmium analyses (0.21 mg/kg) should be used as the background level of these analytes in both surface and subsurface soil.
[b]Below detection.

# 1. INTRODUCTION

The objective of this report is to document the efforts of the Background Soils Project for the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky. This project was started in 1996 to determine the background concentration levels of selected naturally occurring metals and radionuclides in soils from uncontaminated areas in proximity to the PGDP. Planning for this project is presented in the *Project Plan for the Background Soils Project for the Paducah Gaseous Diffusion Plan, Paducah, Kentucky* (DOE 1996b). The intent was to sample surface soils and deep geologic media from uncontaminated sites near the PGDP. To do this, surface soils were sampled within a 6- by 12-mile area west-northwest of the PGDP. For deep geologic media, samples were taken adjacently to but south and west of the site. Both sites are upgradient to prevailing winds and groundwater hydraulic gradients.

The major function of the PGDP is the enrichment of uranium, and the facility has been operational since 1951. A general description of the plant facilities and a brief description of its operating history are available in the project plan (DOE 1996b). Presently, there may be a need to conduct remedial actions at the facility to correct possible contamination of soil and groundwater. Before these actions are conducted, it is important to define and understand the levels and ranges of naturally occurring constituents in soils. Such definition and understanding will allow effective remedial investigations and remedy selection and aid significantly in identifying "new" release locations, if any.

A number of studies or programs were conducted over the years to determine the impact of the facility on concentrations of potential contaminants in soils and groundwater immediately next to the site. Part of these studies has centered on determining reliable information as to background concentrations in soils. A large fraction of the background data was accumulated as part of the Phases I and II Site Investigations (CH2M Hill 1991, 1992). These investigations were completed because of a consent agreement between the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA). A summarization of these efforts is available in Appendix A of the project plan (DOE 1996b).

It was concluded that the database concerning environmental concentrations of organic compounds, inorganic analytes, and radionuclides was very extensive. These studies suggested that no additional effort was needed to establish the background concentration of man-made organic compounds because concentrations of such compounds were not detected with any great frequency in samples collected during the Phases I and II Site Investigations. However, there were several data inadequacies with respect to inorganic analytes and radionuclides that prevented the establishment of a complete and defensible database (with respect to regulatory compliance) for background concentrations in soils and deep geologic media. For example, the DOE (1996a) report on background concentrations of metals in soils at PGDP concluded that some analytes were suspect because of inadequate data or because the estimated background concentrations were much higher than expected. Moore (1995) also concluded that the available database for radionuclides was not adequate to establish the background activities nor was the available database defensible from a regulatory viewpoint.

To provide a rigorous framework by which the technical approaches, project objectives, and data quality could be defined, the EPA Data Quality Objective (DQO) process was used (EPA 1993).

This process involves seven-steps, which are described in detail in the project plan (DOE 1996b). The seven steps involved:

1. Defining the problem
   - Specifying the purpose of the project
2. Identifying the major decisions
3. Defining inputs to the decision process
4. Defining the boundaries of the study
   - Select analytes and detection levels required
5. Developing a decision rule
6. Specifying acceptable limits on decision errors
7. Optimizing the design

Some major decisions involved the definition of background and how to determine the difference between background concentrations and likely contamination. Background was defined by the concentrations of certain metals and radionuclides contained in natural/geologic components in existence before activities at PGDP or sources not associated with PGDP (e.g., atmospheric fallout and agricultural sources). Non-background constituents include man-made components and potential contaminants attributable to activities at PGDP since initial start up of operations, such as $^{99}Tc$ and elevated levels of uranium isotopes. To delineate differences between background and non-background concentrations, the focus was concentrated on establishing a distribution of background populations and estimating means and 95%th percentiles of the analyte distributions. Upper tolerance bounds for the 95th percentile of background distributions were then used to define where background ends and likely contamination begins.

The technical objectives of this work were to (1) determine the background concentration levels of selected inorganic/metals and radionuclides in undisturbed surface soils and deep geologic media, (2) provide validated and defensible baseline data for contaminated site assessment, and (3) provide the data needed to evaluate risk from constituents in background soils for comparison with risks from contaminated sites.

To accomplish these objectives, the work was conducted as outlined in the project plan (DOE 1996b) and managed under the DOE and Lockheed Martin Energy Systems, Inc. (LMES) management structure for the Environmental Restoration (ER) Program at PGDP. The staff organization and functional responsibilities are described in the project plan (DOE 1996b).

# 2. METHODS AND MATERIALS

## 2.1 SELECTION AND COLLECTION OF SAMPLES

An area measuring approximately 6- by 12-miles west-northwest of the PGDP was selected as a sampling site for surface soils. The decision to collect surface samples from this area was based primarily on the premise that this represented an area "up wind" from the PGDP, thereby reducing the possibility that these soils may have been contaminated due to local deposition of washout and dry-fallout of potential contaminants emanating from the PGDP. Selection of surface soils was based on land use history, conformance with classification of soils similar to those at the PGDP, parent material, bedrock formation, geomorphology, and hydrology. Sampling of deep geologic media was centered on the collection of samples upgradient in the dominant hydrologic units and geologic formations ranging in depths from 3 to 30 ft immediately south and southwest of the PGDP in the Kentucky Wildlife Management area. Locations of the samples taken are presented in Fig. 2.1.

### 2.1.1 Soils

Dominant soils within and next to the PGDP belong to the Calloway-Henry soil association group. This soil association group consists of nearly level, somewhat poorly drained, and medium-textured soils on uplands (SCS 1976). These soils have been developed from loess deposited during and after withdrawal of the recent glaciation periods, the Illinoian and Wisconsinan, approximately 12,500 years ago. Loess is an unstratified, fine-grained material, dominantly composed of silt-sized particles, transported by wind from major river valleys. Natural drainage ways dissect the association where the upland soils (the Calloway and Henry series) make up approximately 70% of the association.

Composite samples were taken from three soil series in this association. The soil series comprises the Calloway, Henry, and Falaya soils. The Calloway soil series is the most prevalent upland soil; these are somewhat poorly drained soils formed in thick loess on broad, nearly level to gently sloping uplands. The Henry soil series consists of deep and more poorly drained soils than the Calloway. This soil series was also developed on loess deposits on the uplands and terraces and generally have slopes less than one percent. The Falaya soil series makes up the soils generally found down slope from either the Calloway or the Henry series. These are the soils on level or nearly level, wide floodplains formed in deposits of silty alluvium from loess. These soils are somewhat poorly drained, moderately permeable soils that are subject to flooding and are saturated with water to soil depths of 31 to 61 cm during periods of high rainfall. The general pattern of the landscape position for these soils is illustrated in Fig. 2.2. Detailed characterizations of these soil series plus profile descriptions are available in Appendix B of the project plan (DOE 1996b).

#### 2.1.1.1 Selection of sampling sites for soils

Selection of sampling sites involved two processes: (1) a random selection procedure to identify potential sites on the soil survey map from which samples could be taken and (2) field site inspections of these randomly selected sites. The first process involved taping together three soil survey map sheets (obtained from the SCS) that represented the soil sampling area identified in Fig. 2.1. A 1000-ft square grid (oriented north south and east west) was imposed on this base map. A number and letter identified each cell within this grid. A random number generator was used to select a grid cell randomly. Using the soil survey maps and written descriptions of these soils, the soils inside the grid were evaluated as to their potential suitability as a sampling site. This process

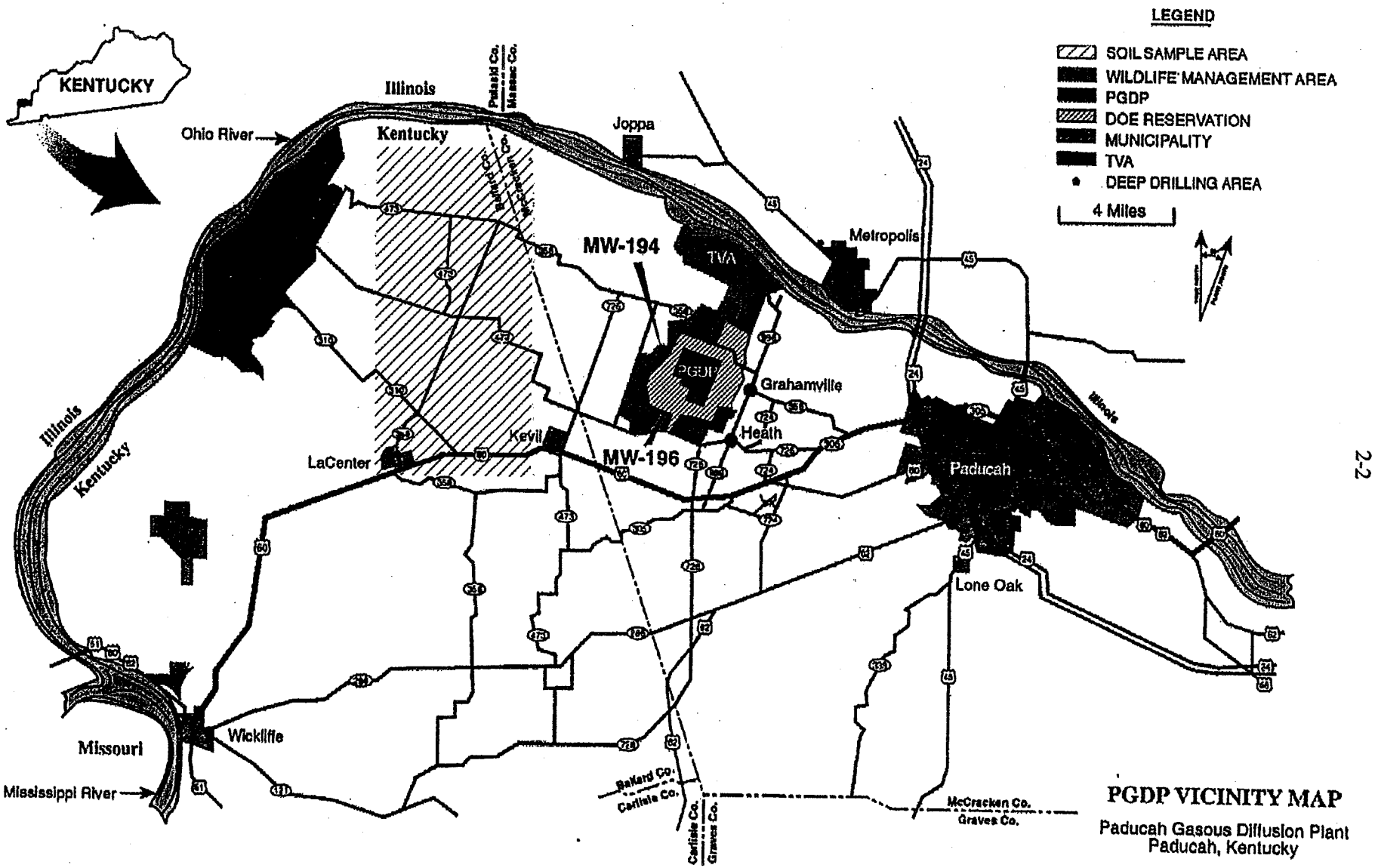


**Fig. 2.1. Vicinity map around the PGDP showing soil sampling area and drill sites.**

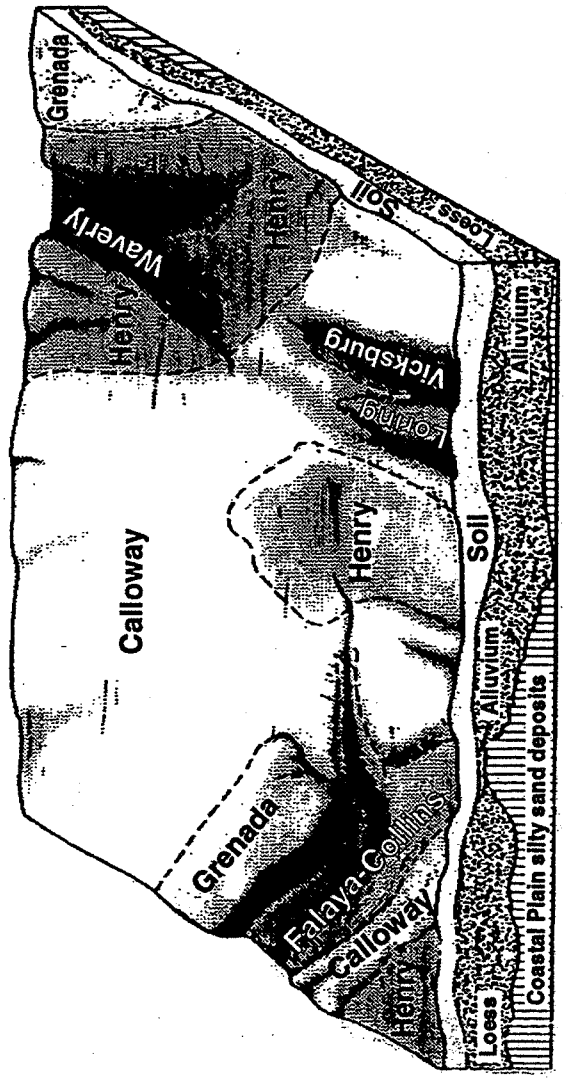


**Fig. 2.2.** Typical pattern of soils and underlying material in Calloway-Henry association.
*Source:* SCS (1976)

continued until an excess number of potential sites had been identified for the named soils of greatest extent. However, the random grid cell selection process did not work well for the soils identified as "Henry" because the Henry soils were small in extent and had to be in undisturbed wooded areas. The random selection process was ended once it failed to place grid cells that contained Henry soils. Finally, it became necessary to place grid cells that contained woodlots with Henry soils. The selection process finally identified 36 potential sites for each soil series; this was three times more than the number of sites needed to be sampled. The remainder of the selection process would involve field identification and assessment of availability (predicated on consent of the landowner to take samples).

After completion of the previously described process to identify potential sites, the Ballard County, Kentucky, Natural Resources Conservation Service (NRCS) Office was contacted to assist in selecting field sites and in identifying and making contact with the landowner for each site in question. The technical coordinator for the project also obtained landowner names and addresses from the Ballard County Courthouse Property Assessor's office. A letter was then prepared and sent by the Plant and Soil Science Department of The University of Tennessee to each landowner describing the sampling process and requesting permission to sample on their land. Many landowners did not grant permission; therefore, the number of potential sites was quickly reduced. As fieldwork started, it became necessary to talk with landowners or converse with them in advance on the telephone. Finally, because of additional ownership changes or lack of permission, it became necessary to find some additional sites on land for which permission to sample had already been granted.

#### 2.1.1.2 Field work and sample collection for soils

All of the soil sampling was confined to Ballard County (see Appendix A for map with locations of soil sample sites and detailed descriptions of soil profiles). In certain instances throughout published reports generated in the remedial investigation/feasibility study processes, there has been some confusion as to the scientific terminology used by soil scientists, geologists, hydrologists, and engineers to describe soils, geologic media, and hydrologic conditions. To avoid possible confusion in the terminology used in this report (especially those relating to soils), some working definitions are presented in Table 2.1.

**Table 2.1. Working definitions used in this report.**

| Scientific Term | Working Definition Used in This Report |
|---|---|
| Soil | Earthy material modified by physical and chemical weathering processes and further modified by biologic and biochemical processes (soil forming processes) such that it will support the growth of living organisms (soil scientist definition) or unconsolidated earthy material or regolith (geologist definition). The term "regolith" will be used in place of "soil" if there are any geologic connotations in the discussion. |

**Table 2.1. (continued)**

| Scientific Term | Working Definition Used in This Report |
|---|---|
| Soil Series | A soil series is defined by soil scientists as earthy material modified by a soil forming process so that there is a particular expression of genetic layers or soil horizons that are unique and which serve to identify a particular kind of soil. Each soil series is named and classified. In this report, the following soil series names, based on the Ballard County Soil Survey Report were identified. These soils series names are: Calloway, Grenada, Henry, Falaya, Vicksburg, and Waverly. In this report, Calloway soils represent all soils belonged to Calloway-Grenada association and Falaya soils represent all soils belonged to Falaya-Vicksburg-Waverly association. A soil association is a landscape that has a distinctive proportional pattern of soils. It consists one or more major soil series and at least one minor soil series. |
| Soil Horizon | A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming processes. A soil profile has two or more of the following major horizons: (1) *O horizon* - The layer of organic matter on the surface of mineral soil. (2) A horizon - The mineral horizon at the surface or just below an O horizon. This horizon is the one in which organisms are most active. Ap horizon is a mineral horizon that has been plowed. (3) E horizon - An eluviated mineral horizon above the B horizon. (4) B horizon - A subsurface mineral horizon underneath of the surface horizon. The B horizon is in part a layer of change from overlying A to the underlying C horizon. (5) C horizon - The weathered rock or loess material immediately beneath the solum. This material is presumed to be like that from which the overlying horizons were formed. |
| Formation | A geologic term used to identify particular rock units or regolith units. In this report the following names are used: Holocene-Modern Alluvium, Quaternary Alluvium, Quaternary Loess, Quaternary Continental Alluvium Deposits, Jackson-Claiborne-Wilcox (otherwise commonly called "Eocene Sands"), and Porters Creek Clay. Geologic criteria were used to identify each of these Formations in the sampling areas of Ballard and McCracken County (DOE, 1996). |
| Hydrogeologic Unit (HU) | The "HU" term in this report is related to water movement in certain geohydrologic strata in the regolith underlying the A & B surface soil horizons. They are further defined in Table 2.2. |

Soil samples were collected from the A and B soil horizons. The surface most soil layer or soil horizon was either an Ap horizon if the site had been plowed or an A horizon if the site was in a woodlot that had not been plowed or cultivated. The A horizon of a soil consists of the surface mineral layer of the soil that contains considerable organic carbon. The A or Ap horizon is also commonly termed "topsoil" in general terms. The middle of the B horizon or subsoil was also sampled at each site in Ballard County. All of the surface (A horizon) and subsoil (B Horizon) samples were in either Quaternary loess, Quaternary alluvium from loess, or Holocene/Modern alluvium identified by the presence of pebbles and higher sand content and located on the low terrace or floodplain landform.

Surface A or Ap horizon samples were collected in the following manner. The soil scientist responsible for identifying the soil series first entered the sampling site. After several test holes were evaluated, a decision was made about whether the site had suitable soils based on the criteria established in the sampling plan (DOE 1996b). If these criteria were met, a 10 × 10 ft area was

flagged at the corners. The thickness and depth of the A and B horizons were determined from which the samples would be collected. The sample collecting team of two soil scientists entered this square and carefully removed any surface litter. Samples were taken of the A or Ap horizon using a pre-cleaned and field rinsed stainless steel 3 1/4"-diameter auger. The soil material was placed into a stainless steel bowl and carefully mixed and sample bottles were filled and labeled.

After sampling the A horizon, the same auger was used to bore to the top of the B horizon. After changing gloves and bringing in pre-cleaned sampling equipment, a 2 3/4"- dia. stainless steel auger was carefully inserted into the larger auger hole so as not to contaminate the side of the auger barrel. Samples were obtained from the full depth of the B horizon, placed into a stainless steel bowl, mixed well, and sample jars were filled and labeled. During the sampling, another soil scientist documented the procedure and wrote a complete description of the soil profile. The purpose of the soil profile description was to verify that the soil series was correctly identified and classified and that the samples collected were at the proper depths. After sampling was completed, the auger holes were filled and the corner flagging removed leaving the site as undisturbed as possible. Ninety soil samples, including 18 field duplicates, were collected. These samples represented an equal number of individual soil series and horizons.

When the Ballard and McCracken Counties Soil Survey was made, most upland soils were thought to have had a fragipan. However, no fragipans were identified in any of the upland soil sites in Ballard County. Therefore, the soils were classified, using current Soil Taxonomic criteria, as non-fragipan soils, and different soil series names were attached. The field assistance of NRCS soil scientists at some sites provided additional expertise needed in classifying the soils and assigning soil series names. The only soil series that fit current series concepts were the Falaya and Waverly series. The soil series concepts of the Grenada, Calloway, and Henry series in the published soil survey required these soils to have a subsoil fragipan. However, no fragipans were identified at any of the sample sites. Consequently, the names used to identify what was once considered Grenada, Calloway, and Henry could no longer be used. Except for the lack of a fragipan, all other series criteria (e.g., such as parent materials, soil-forming process, drainage class) had not changed. The changes in soil series names do not affect the validity of the surface and subsurface soil background samples collected.

To assess the potential for cross-contamination during soil sampling, rinseate water was collected after rinsing the sampling tools at the H-9 and F-21 soil sampling sites. These samples were submitted for analyses for metals and radionuclides.

### 2.1.2 Deep Geologic Media

The loess-derived soils overlie sedimentary deposits transported from the central part of the North American continent and deposited in what is called the Mississippi Embayment. These deposits generally consist of fine- to medium-grained clastic materials overlying Paleozoic bedrock. The major components are the Upper Continental Deposits, the McNairy formation, the Porters Creek clay, and the undifferentiated, discontinuous Eocene sands (see Fig. 2.3). Within the Upper Continental Deposits, five hydrogeologic units (HU) have been identified (Clausen et al. 1992). The hydrogeologic units (HU-1, HU-2, and HU-3) have been sampled and are described in Table 2.2.

#### 2.1.2.1 Sampling site selection for deep geologic media

The deep drilling sites were in McCracken County south and west of the PGDP in the Kentucky Wildlife Management area. The collection of deep drilling samples brought the HU criteria into

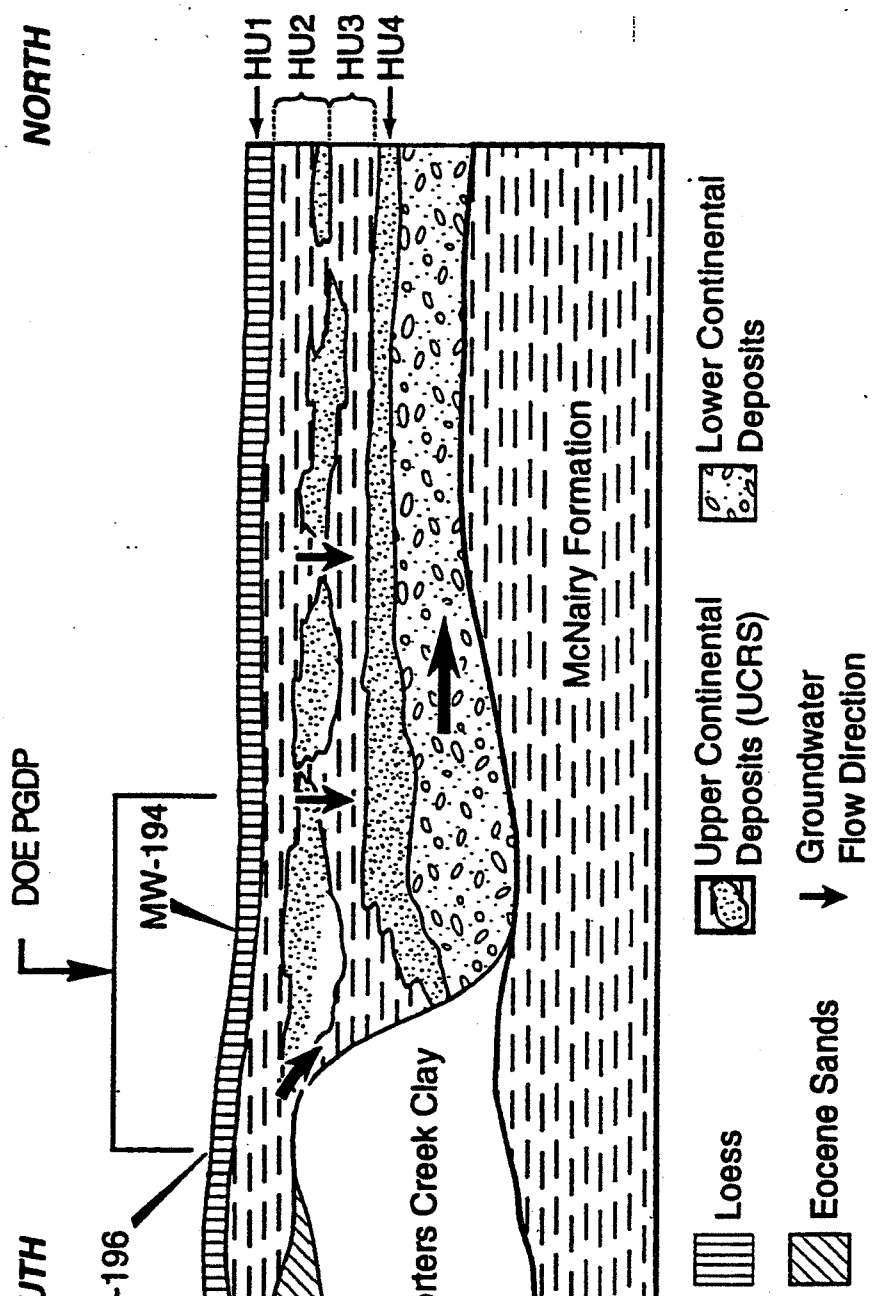


**Fig. 2.3. Schematic of the north-south section showing regional stratigraphic relationships and HU 1 through HU-4.** *Source: Clausen et al. 1992.*

**Table 2.2. Characteristics of the hydrogeologic units (HUs) sampled.**

| HU | Description of Characteristics |
|---|---|
| HU-1 | This unit encompasses the Late Pleistocene loess that blankets the site. The soils in this loess unit contribute to the rapid development of mostly vertical water flow pathways close to the soil surface. Water flow pathways are easily identified by the presence of gray, low-clay-content silt between polygons. Clay polygons result in another perched zone at the contact of the loess with the next lower HU. |
| HU-2 | This unit is the area in which most of the upper continental recharge system occurs. It consists of discrete sand and gravel bodies within a fine-grained alluvial deposit. |
| HU-3 | This unit is the confining layer for the regional gravel aquifer (RGA). It is composed of clay, silt, or clayey silt sediments from the base of Unit 2 to the top of Units 4 and 5. Units 4 and 5 (not sampled for this study) consist of mostly sand and gravel and comprise the RGA. |

focus. The soil scientists on the project were responsible for collecting samples. To ensure that the proper samples were taken several geologists were consulted to identify positively that the desired HUs were sampled[2]. These sampling sites included two sites to the south and three sites to the west of the plant. Two field duplicate cores were taken at each site. The intent was to collect samples from predetermined formations and hydrogeologic units as described in the project plan (DOE 1996b).

The south sites near groundwater monitoring well (MW) No.-196 were selected to collect loess, Eocene sand, and Porter's Creek clay samples, and the west sites near MW194 were selected to collect loess (HU-1) and HU-2 and HU-3 samples (Appendix B). The Porter's Creek clay stratum was sampled near the west site instead of a south site because it was not possible to reach the Porter's Creek clay stratum at the south site with the drill rig. Samples for the HU-1 units were taken from the bottom part of the unit because the upper portion of the loess was collected during sampling of the A and B horizons of the surface soils.

To ensure that the drilling did not take place in contaminated sites, samples were taken at elevations higher than known contaminated areas in the plant. In addition, the drill sites were on interfluves between uncontaminated drainage ways. These selected geologic formations and hydrogeologic units represent the major subsurface geologic components in the contaminated areas of PGDP.

### 2.1.2.2 Field work and sampling of deep geologic media

The HU-1, the hydrogeologic unit immediately below the soil's B horizon, consists of a Quaternary loess deposit. Within this Quaternary loess, there was a truncated paleosol identified by changes in color, texture, and a clay enriched Bt horizon. Beneath the Quaternary loess at several drill sites, there was a layer of Quaternary alluvium derived mostly from loess, but this alluvium also contained a sand content that would be considered too high for the regolith materials to be classified as loess, as it also contained a few small pebbles. This alluvium layer was identified by the HU-1L designation (for summary purposes, such as those presented in Tables 3.1 and 3.2, these analyses were included in the HU-1 statistics).

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[2]K.R. Davis, Lockheed Martin Energy Systems, Paducah Environmental Restoration, personal communication with S.Y. Lee, Oak Ridge National Laboratory.

Beneath the Quaternary loess or Quaternary alluvium, there was an abrupt change to stratified materials ranging from high silt to high sand content and identified as the Quaternary continental alluvium. The content of small gravels also increased. Samples were collected of the high silt plus clay content strata and identified as HU-2. At the top of HU-3, there was another truncated paleosol at several drill holes; this paleosol was identified by the presence of pedologic soil structure in contrast to any geologic structure in a clay enriched Bt horizon. Unit HU-3 was identified in the field by its higher bulk density and higher silt plus clay content. At the south drill site locations, this HU-3 unit was absent and Eocene sands underlay the HU-2 unit. Samples were collected of the red sandy materials, the mottled yellowish brown reduced sandy materials, and the reduced clayey stratum that was positioned above the upper Eocene sands. The Eocene sand samples were collected form cores taken above the reduced clayey stratum. The sand stratum underneath the clayey layer was not collected for analyses.

At the west drill site locations, the Eocene sands were missing and the Porters Creek clay was encountered immediately beneath the Quaternary continental alluvium deposits. Again, there was a truncated paleosol in the top of the Porters Creek clay that was identified by the presence of pedologic soil structure in a clay-enriched subsoil Bt horizon. The Porters Creek clay was also quite highly oxidized to a brown color and had or was still undergoing an acid-sulfate weathering process. The Porters Creek clay contains abundant pyritic materials. Jarosite, a by-product of acid-sulfate weathering, was identified on some crack faces in the drill core. One major difference in the Porters Creek clay samples collected at this site as compared to Porters Creek clay samples beneath the PGDP is the apparent difference in oxidation state. Samples at this site appear to be oxidized (brownish to red colored) in contrast to the unoxidized black color of the Porters Creek clay beneath the PGDP. Locations of drill sites and detailed descriptions of the drill cores and intervals used for composites are presented in Appendix B.

Collecting samples from the deep drill coring operation required different procedures to reduce any cross contamination. The drillers were responsible for cleaning and rinsing their equipment. To collect clean samples, a plastic sleeve was fastened to a core point sealed with an "O" ring. The sleeve and coring point were attached to a steel coring tube. The coring tube was driven into the ground to the required depth and the core point unscrewed allowing access of the regolith into the core. The coring tube was then driven to its full depth to fill the plastic inner sleeve. The drill rods and coring tube were then removed from the drill hole and the regolith filled plastic tube was removed. The exterior of the tube was immediately cleaned and labeled and the ends capped.

After the drilling was completed at a site, the sample tubes were transported to an office trailer and laid out on a table. A knife was used to split the plastic sleeve in two places. The top half of the plastic sleeve was removed allowing access to the core. A clean knife was used to remove a small section of the entire length of the core. This regolith material was placed in the top of the sleeve and was used to describe the core and then discarded. The observable properties of the exposed core were used to determine both the geologic formation and the HU.

After sampling sequences were determined, the samplers, using clean gloves, picked up small sections of the core and placed them into precleaned sample jars. After each jar was filled and capped, a label was completed and attached. Clean sampling tools and gloves were used each time there was a change in either the geologic formation or the HU; this procedure was followed throughout the drill core sample collecting activities. However, some deviations occurred to this drill core sample collection procedure. Whenever the core was collected from a perched water zone in the drill hole, it was necessary to rinse the soil core after the plastic sleeve had been removed with deionized distilled water. Rinsing of the soil core in this manner was intended to remove any

entrained contaminated water remaining within the core as a consequence of it being removed from a perched water zone.

Great care was taken during the drill core sampling activities to prevent or to minimize any cross contamination across core samples. For example, two rinseate water samples were collected from the cutting ends of the coring equipment and acetate sleeves before coring at site 196. Analyses of these rinseate samples revealed no detectable levels of metals or radionuclides (see Sect. 2.3, Data Validation). After a drill core had been fully described and sampled, the debris was removed from the table, the table surface cleaned, and a clean sheet of plastic laid out to prevent cross contamination of the next set of drill cores.

### 2.1.3 Composite Sample Preparation

All field samples were transported to a clean-secured laboratory in Building 1505, Environmental Sciences Division, Oak Ridge National Laboratory. The accountability of each sample was assured by using an approved chain-of-custody procedure. Samples were then individually placed on clean blotting paper to dry before sieving through a 2-mm stainless steel sieve. For most samples, the quantity of gravel fractions (>2 mm) was insignificant.

For the compositing of surface soil samples, samples from 12 sites from one of the same soil series (Calloway, Falaya, or Henry) were sub-divided into four groups by randomly selecting three soil samples. An equal amount (700 g or more) of the three sieved samples having an equivalent soil horizon and equivalent soil series was composited by mixing in a stainless steel bowl. After mixing of the soils with a stainless steel spoon, the composited sample was stored in two precleaned, one-liter, polypropylene bottles. The sampling site numbers for each composite sample were recorded (see Appendix C).

For the deep geologic strata samples, several composites were prepared by mixing equivalent hydrologic units or formations from two cores collected from each drill sites. The intended plan was to collect eight cores from two drill sites (a total of 16 cores according to the project plan, DOE 1996b). However, because of an inability to sample the Porters Creek clay at the south site, four additional cores were taken at the west site making a total of 20 cores instead of 16 (Appendix B).

Deep-soil compositing was conducted by placing two individual core segments on clean blotter paper. After partially drying, the cores were desegregated (broken up using a pistil and mortar and then sieved through a 2-mm screen). An equal amount (900 g or more) of the two sieved samples from an equivalent hydrologic unit or formation was transferred in a stainless steel bowl. After mixing of the two samples with a stainless steel spoon, the composited sample was transferred to two precleaned, one-liter, polypropylene bottles for storage and subsequent analysis. The drill site numbers for each of the composited samples were recorded (see Appendix C).

After each bottle was filled and capped, a label was filled out and attached. Labels for bottles were made out as samples were prepared. Sample numbers were first filled out in the laboratory notebook and then copied to labels. Chain-of-custody forms were filled out from the labels. One of the two bottles containing the composite sample was sent to Lockheed Analytical Services (LAS), a component of Lockheed Environmental Systems & Technologies Co., Las Vegas, Nevada, for analyses. The total number of composite samples sent to LAS included 30 soil samples and 26 deep stratum samples. Sample material in the replicate bottles was used for other analyses: (1) neutron

activation analyses (NAA), (2) the determination of radionuclides by the Kentucky State Laboratory, and (3) particle size determinations by The University of Tennessee, Knoxville.

During the composite sample preparation, three rinseate waters were collected after rinsing the mixing bowl, spoons, etc. These samples as well as two demineralized source waters (one from PGDP used during field work and the other water from Building 1505 used during laboratory composite sample preparation work) were analyzed for the targeted metals and radionuclides.

### 2.1.4 Quality Assurance for Collection of Field Samples and Sample Preparation

Measures to ensure high standards of quality control included keeping careful notes in a bound field notebook plus field audits and observations. Any and all observations and suggested alterations in field procedures by the field audit team were immediately reviewed by the sampling team members and incorporated into all future sampling activities. Any possible problems with samples already collected regarding possible contamination or chain-of-custody concerns were also immediately addressed. For example, one of the primary concerns of the field audit team dealt with the sequence in time for completing chain-of-custody forms. The audit team requested that the chain-of-custody forms be completed immediately after sampling rather than waiting until the end of the day. This corrective action was immediately implemented, and no samples were discarded as the result of field auditing. All changes and any deviations from standard field collection procedures were recorded in the field notebook.

The procedures for collecting samples from the hydrogeologic units were developed in the field because the thicknesses and characteristics of the HUs and formations were unknown prior to core retrieval at each sampling site. This involved developing a protocol for collecting the core, establishing a format in which the visual characteristics of the core could be documented, and then developing the method for removing a representative sample from the core.

All sampling sites were carefully screened in advance by a soil scientist member of the sampling team. If the site was not representative of the soil series, it was abandoned and the team went on to the next site. If a site was deemed to represent the desired soil series, a 10 × 10-ft-square area was flagged. A prescreening of the flagged area was conducted next to determine if the site possibly contained higher than background levels of radionuclides or indicated a presence of volatile organic compounds. If either of these conditions appeared to be the case, the site would be abandoned. Only the sampling team (which was composed of two predetermined individuals) was allowed into the field site to collect samples. Each member of the sampling crew had clearly assigned duties and responsibilities at each sampling site to ensure that all sampling activities would be conducted in a consistent manner. Labels for jars were completed as samples were collected. Sample numbers were first filled out in the field notebook and then copied to jar labels. Chain-of-custody forms were filled out from the jar labels. The custody forms were then crosschecked with the field notebook to ensure no errors had been made. Great care was taken by the sampling team to prevent any cross contamination by following all standard procedures.

All of the water samples collected during field work and laboratory sample preparation work were sent to the contract laboratory according to EPA approved procedures for chain of custody, laboratory analyses, and data reporting as described in the project plan (DOE 1996b). Analytical results for these water samples are summarized and presented in the printout of the data package (Appendix D). The resulting analyses of source waters from both PGDP and Oak Ridge National Laboratory (ORNL) sites indicated that all metals and most radionuclides were at concentrations below instrumental detection limits. A few radionuclides were detected but were associated with

large counting errors. The analytical results of rinseate waters showed (1) no detectable levels of the metals, (2) very low activities of radionuclides, and (3) no noticeable difference in analyte concentrations as compared to that contained in the source waters. These results suggest that there was no measurable contamination or cross-contamination during field sampling and composite sample preparation.

## 2.2 SELECTION OF ANALYTES AND METHODS OF ANALYSES

After careful review of the site remedial investigation/feasibility study reports and previous studies dedicated to establishing background concentrations of contaminants at PGDP, a group of risk assessment personnel and soil specialists (in consultation with the state and federal regulatory community) identified a list of analytes for determination. The selected analytes included four metals (Sb, Be, Cd, and Tl) and a suite of radionuclides ($^{40}$K, $^{90}$Sr, $^{99}$Tc, $^{137}$Cs, $^{226}$Ra, $^{228}$Th, $^{230}$Th, $^{232}$Th, $^{234}$U, $^{235}$U, $^{238}$U, $^{237}$Np, $^{238}$Pu, and $^{239}$Pu). To determine these concentrations and activities in soils and geologic media, a statement of work was developed according to procedures set forth by the Martin Marietta Technical Subcontracting Office. The work was awarded based on technical requirements and competitive pricing to LAS. For comparative purposes, ORNL was requested to determine concentrations of $^{232}$Th, $^{235}$U, and $^{238}$U using NAA. Other analyses included particle size determinations on the surface soil and HU1 (loess) samples by The University of Tennessee, Knoxville, soil analyses laboratory.

The methods used in the analyses are listed in Table 2.3. Three methods of analyses (alpha-spectroscopy, ICP-MS, and NAA) were used to determine concentrations of $^{232}$Th, $^{235}$U, and $^{238}$U. The three methods of analyses would allow comparisons between a highly sensitive and accurate nondestructive technique such as NAA with two techniques that require the dissolution or leaching of the analyte from the solid matrix. In the case for alpha-spectroscopy, a nitric acid/hydrofluoric acid dissolution process was used to separate the analyte from the solid soil matrix, while in the case for ICP-MS a less aggressive extraction was employed using a combination of nitric and hydrochloric acids.

**Table 2.3. Selected analytes and method of analyses**

| Analyte | | Type of Analyses | Method of Analyses | Reference |
|---|---|---|---|---|
| **Metals** | Sb | ICP-MS[a] | EPA-6020 | CLP Method 6020[e] |
| | Be | ICP-MS | EPA-6020 | CLP Method 6020[e] |
| | Cd | ICP-MS | EPA-6020 | CLP Method 6020[e] |
| | Tl | ICP-MS | EPA-6020 | NA[c] |
| **Radionuclides** | $^{40}$K | Gamma | EPA-901 | LAL-91-SOP-0063[f] |
| | $^{90}$Sr | Beta/GPC[b] | ASTM-D581 | LAL-91-DOP-0169[f] |
| | $^{99}$Tc | Beta/LSC[b] | EPA-6020 | LAL-91-SOP-0169[f] |
| | $^{137}$Cs | Gamma | EPA-901 | LAL-91-SOP-0063[f] |
| | $^{226}$Ra | Gamma | EPA-901 | LAL-91-SOP-0063[f] |
| | $^{228}$Th | Alpha | NA[c] | LAL-91-SOP-0108[f] |
| | $^{230}$Th | Alpha | NA[c] | LAL-91-SOP-0108[f] |
| | $^{232}$Th | Alpha | NA[c] | LAL-91-SOP-0108[f] |
| | | ICP-MS | EPA-6020 | CLP Method 6020[e] |
| | | NAA[d] | NA[c] | AC-MM-222002[d] |
| | $^{234}$U | Alpha | EPA-908m | LAL-91-SOP-0108[f] |

**Table 2.3. (continued)**

| Analyte | Type of Analyses | Method of Analyses | Reference |
|---|---|---|---|
| $^{235}U$ | Alpha | EPA-908m | LAL-91-SOP-0108[f] |
| | ICP-MS | EPA-6020 | CLP Method 6020[e] |
| | NAA[d] | NA[c] | AC-MM-222002[d] |
| $^{238}U$ | Alpha | EPA-908m | LAL-91-SOP-0108[f] |
| | ICP-MS | EPA-6020 | CLP Method 6020[e] |
| | NAA[d] | NA[c] | AC-MM-222002[d] |
| $^{237}Np$ | Alpha | NA[c] | LAL-91-SOP-0108[f] |
| $^{238}Pu$ | Alpha | NA[c] | LAL-91-SOP-0108[f] |
| $^{239}Pu$ | Alpha | NA[c] | LAL-91-SOP-0108[f] |

Notes:
[a]Inductively Coupled Plasma-Mass Spectroscopy
[b]Beta spectroscopy with gas proportional counter (GPC) or liquid scintillation counter (LSC)
[c]No EPA method available
[d]Neutron Activation Analysis Laboratory, ORNL High Flux Reactor
[e]Methods of Analyses, EPA, SW-846
[f]Standard Operating Procedure, Lockheed Analytical Services, Lockheed Environmental Systems & Technologies, Co., Las Vegas, Nevada

## Quality Assurance for Laboratory Measurements

Measurements made in the laboratory and methods used to manage the data were established in equivalence to what was formerly termed EPA Level III with respect to quality assurance and quality control. The major quality assurance objective was centered on ensuring that the laboratory data were free of errors in determining the concentrations and activities of analytes in soil and deep geologic media. Data management included EPA-approved procedures for chain of custody, laboratory analyses, and data reporting.

Specific procedures and quality assurance/quality control requirements relating to the management of the laboratory data were established in the project plan (DOE 1996). In October 1996, an approach to data assessment for the radionuclide data was developed according to the Environmental Restoration Procedure ERWM/ER-P2209, Radiochemical Data Verification and Validation (see Appendix E). To ensure that these procedures and requirements were followed, a surveillance plan was developed by the quality assurance/quality control project officer. This plan was directed at assessing (1) the methods used in receiving the data from the analytical laboratories; (2) how the data were verified and validated; (3) the method of record storage; (4) the ease in which the data could be retrieved; and (5) the methods in place to protect the data from damage, deterioration, or loss.

Surveillances were conducted during the months of November and December of 1996 and reported to the program manager and project manager in January 1997[3]. In summary, there were no new or negative findings in the surveillance. The report did, however, contain one positive observation and another recommendation with respect to documentation and maintaining a record of the verification and validation process. These recommendations were immediately implemented once brought to the attention of the investigators.

[3]Surveillance report #96BSPP-2, January 3, 1997, T. M. Koepp, ER-TI-QA Department, Building K1330, MS-7298.

## 2.3 DATA VALIDATION

A defined and documented process (Energy Systems 1992 and 1995) ensured the quality of the data validation. The initial step involved screening the data packages for completeness of project deliverables. Its major objective was to determine compliance by the analytical laboratory and with respect to the statement of work described in the procurement process. Data were then reviewed and evaluated against the project-specific data validation criteria. For example, the entire metals' database (determined by ICP-MS) was formally validated; however, validation for the radionuclides was conducted on a "case-by-case" basis depending on selected criteria. Verification and validation notes and observations were documented with flags and tabs within the data package and form one sheets. Major emphasis was directed at validating the results of the uranium and thorium analyses by alpha spectroscopy. The intent was to identify possible outliers and potential errors in analyses by comparing activity ratios of $^{235}U/^{238}U$, $^{228}Th/^{232}Th$, and evidence of non-secular equilibrium in the activity of daughter and parent radioisotopes; this process is described in more detail in Appendix E. Analyses of $^{232}Th$, $^{235}U$, and $^{238}U$ by alpha spectroscopy were also compared with analyses by NAA and ICP-MS procedures.

A total of 14 data packages was processed. The 14 included 10 data packages for radionuclides (five reporting gamma spectroscopy, four the alpha and beta analyses, and one containing the analyses by neutron activation analyses) and 4 data packages for metals (ICP-MS analyses). The final database contained very few non-detects. For example, >98% of all analyses for the radionuclides (using alpha, beta, and gamma spectroscopy methods) were characterized as detections. All (84) analyses by NAA were above non-detection limits. The exceptions were metal and radionuclide analyses by ICP-MS. In the cases for antimony, cadmium, and $^{235}U$, all samples analyzed by ICP-MS were below detection limits. Other non-detects included analyses of thallium by ICP-MS where only 36% of the samples were characterized as detects. Seven percent of the samples were considered no-detects for beryllium (Table 2.4).

**Table 2.4. Summary of number of detects and non-detects**

| Method of Analysis | Analyte | Number of Detects | Number of Non-Detects | Per Cent Detects |
|---|---|---|---|---|
| α, β, and γ Spectroscopy | Radionuclides | 1146. | 23. | 98. |
| ICP-MS | Antimony | 0. | 56. | 0. |
| | Beryllium | 52. | 4. | 93. |
| | Cadmium | 0. | 56. | 0. |
| | Thallium | 20. | 36. | 36. |
| | $^{232}Th$ | 56. | 0. | 100. |
| | $^{235}U$ | 0. | 56. | 0. |
| | $^{238}U$ | 55. | 1. | 98. |
| NAA. | $^{232}Th$ | 56. | 0. | 100. |
| | $^{235}U$ | 28. | 0. | 100. |
| | $^{238}U$ | 28. | 0. | 100 |

The contract laboratory (LAS) reported 1561 results. Approximately 80% of these results (1242) were not assigned data qualifiers. A summary of the data qualifiers partitioned according to methods of analyses is presented in Table 2.5. Most of the data qualifiers (209) were associated with the inability to determine detectable levels of antimony, cadmium, and $^{235}U$ by ICP-MS. However, there were 69 instances where measurements by ICP-MS were less than the required detection limit but still greater than or equal to the instrument detection limit.

**Table 2.5. Summary of data qualifiers assigned to analytical data from the contract laboratory**

| Method of Analyses. | Laboratory Qualifiers Used*. | | | | | | | Total. |
|---|---|---|---|---|---|---|---|---|
| | None. | B. | F. | F & B. | Y. | U. | U & N. | |
| Alpha. | 362. | 10. | 5. | 1. | 3. | 0. | 0 | 381 |
| Beta | 71. | 0. | 0. | 0. | 0. | 0. | 0. | 71. |
| Gamma. | 695. | 22. | 0. | 0. | 0. | 0. | 0. | 717. |
| ICP-MS. | 114. | 69. | 0. | 0. | 0. | 179. | 30. | 392. |
| Total. | 1242. | 101. | 5. | 1. | 3. | 179. | 30. | 1561. |

Note:
*See Appendix F, Analytical Data Qualifiers used by Lockheed Analytical Services.

Data validation at ORNL did not reject any of the analytical data received from the contract laboratory. Using the criteria defined in Appendix F for data validation qualifiers, 418 results were validated. This included all of the analyses determined by ICP-MS and 26 measurements dealing with radionuclides (following that outlined in Appendix E). A summary of the data validation process is presented in Table 2.6. Greater than 90% (378) of the 418 concentrations and activities determined as background soil levels were not assigned a validation qualifier.

**Table 2.6. Summary of data validation qualifiers assigned to background soils data**

| Analytical Method. | Analyte. | Data Validation Qualifiers. | | | Total. |
|---|---|---|---|---|---|
| | | None. [a] | J[b]. | UJ[c]. | |
| Alpha | $^{234}U$ | 0. | 1. | 0. | 1. |
| Alpha | $^{238}U$ | 1. | 0. | 0. | 1. |
| Gamma | $^{235}U$ | 0. | 1. | 23. | 24. |
| ICP-MS | Antimony | 55. | 1. | 0. | 56. |
| | Beryllium | 52. | 4. | 0. | 56. |
| | Cadmium | 55. | 1. | 0. | 56. |
| | Thallium | 53. | 3. | 0. | 56. |
| | $^{232}Th$ | 55. | 1. | 0. | 56. |

**Table 2.6. (continued)**

| Analytical Method. | Analyte. | Data Validation Qualifiers. | | | Total. |
|---|---|---|---|---|---|
| | | None. [a] | J[b]. | UJ[c]. | |
| | $^{235}U$ | 55. | 1. | 0. | 56. |
| | $^{238}U$ | 52. | 4. | 0. | 56. |
| Total | | 378. | 17. | 23. | 418. |

Notes:

[a]Data were validated and concurs with qualifiers used by analytical laboratory.

[b] Analyte, compound or nuclide identified; the associated numerical value is approximated.

[c]Analyte, compound or nuclide not detected above the reported detection limit, and the reported detection limit is approximated due to quality deficiency.

## 2.4 STATISTICAL METHODS

The statistical analysis focused on the primary target analytes (including total uranium). The analytes, antimony and cadmium, were not included in the statistical analysis because they were not detected. The primary statistical endpoints were means and 95% confidence bounds for means, estimates of 95 percentiles and 95% confidence bounds for the percentile estimates, which are called tolerance bounds. The placement of these statistical endpoints within a normal distribution model is graphically illustrated in Fig. 2.4.

The statistical analysis was performed in several steps. First, for each analyte, all data were plotted to check for outliers and assess whether a normal, lognormal, or some other parametric statistical model would be a reasonable approximation to the actual analyte distribution. A parametric distribution is necessary here, because there are too few observations in each area of interest (e.g., series-horizon) to allow for a nonparametric analysis, based for example on percentiles. More formal goodness-of-fit tests were also performed to check distribution approximations. On the basis of the graphics and goodness-of-fit tests, the normal distribution was selected as the statistical model for data analysis.

Next, mean concentrations in the various series/formations and horizons/units were estimated and compared. Different approaches were taken to do this for deep and surface soils. For surface soils, because the background survey design accounted for both laboratory error (via sample duplicates) and spatial error (via spatial sampling), analysis of variance was used to estimate mean analyte levels to compare the means across horizons and series and estimate laboratory and spatial components of variance. To properly compute percentile estimates and tolerance bounds, it is necessary to estimate both the laboratory and spatial variance components because the percentiles of the distribution of a composite are tighter than the percentiles of an ordinary (noncomposite) sample (composites are less variable).

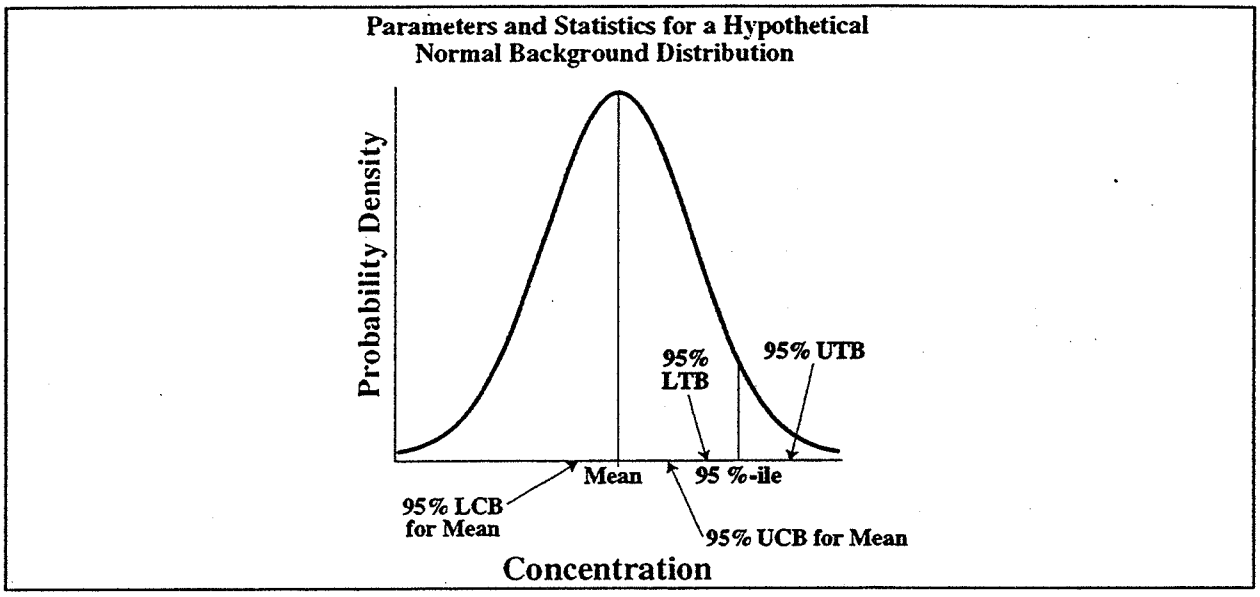


**Fig. 2.4. Statistical endpoints used to demonstrate population distribution of activities and concentrations of target analytes for a normal distribution model.**

For the deep soil results, which were not intended for assessing spatial variability, only laboratory error was considered in the data analysis. Because of the deep-soil survey design, analysis of variance could not conveniently be used for the statistical analysis, and so specific means, comparisons, and standard errors were calculated by specifically coding for them (in a SAS data step). For both deep and surface data a special analysis was also made for thallium, for which there was a mixture of detects and nondetects. The thallium analyses are based on normal-model maximum likelihood estimation, adjusted for nondetection (see Lawless 1982, p 221).

Other statistical analyses performed were: (1) an investigation to determine the possible correlation between analyte concentrations and clay content, (2) a comparison of laboratory and spatial error variability, (3) a comparison of analytical methods (alpha, beta, gamma, ICP-MS, and NAA) to determine selected analytes, and (4) an examination of the conformity of $^{234}U$, $^{235}U$ and $^{238}U$ isotopic ratios. Details relating to the approach and statistical methods used to conduct these analyses are discussed in Appendix G.

# 3. RESULTS AND DISCUSSION

The activities and concentrations of analytes measured in selected soil horizons and hydrologic units are summarized in Tables 3.1 and 3.2, respectively. Results are expressed in a variety of statistical terms: the range, mean (with the upper and lower 95% confidence boundaries), standard error of the mean, and the estimate for the 95%th percentile (with the upper and lower 95% tolerance bounds). These tables also include the number of detects and non-detects measured in the analytical process. Similar statistical results of the radionuclides and metals measured in the surface soils (the A and B horizons of the Calloway, Falaya, and Henry soils) are presented in Tables 3.3 and 3.4, respectively. Comparisons of the radionuclide activities and concentrations of metals among the three soils are illustrated in Tables 3.5 and 3.6, respectively.

## 3.1 DISTRIBUTION AND ACTIVITIES OF URANIUM ISOTOPES

The activities of three uranium isotopes ($^{234}U$, $^{235}U$, and $^{238}U$) were determined by alpha-spectroscopy (these are summarized in Table 3.1). Activities for $^{235}U$ and $^{238}U$ were also determined using ICP-MS and NAA methods. Any differences in activity levels determined by the three processes are discussed in Sect. 3.8, Comparisons Between Methods of Analyses. Alpha-spectroscopy is the method most preferred, and reasons for its preference will also be discussed in the aforementioned section.

The mean activities of $^{238}U$ (the isotope that makes up 99.3% of the total mass of natural occurring uranium in soils) measured in nearly all the soils and geologic media sampled were approximately 1.0±0.2 pCi/g (see Fig. 3.1). The single exception was the relatively low activity (mean of 0.245 pCi/g) measured in the Eocene sands. Note that the activities of $^{234}U$ were slightly larger than those of $^{238}U$. The $^{238}U$ isotope dominates the natural distribution of uranium on a weight basis (i.e., it constitutes 99.27% while $^{234}U$ and $^{235}U$ make up 0.0055 and 0.72%, respectively).

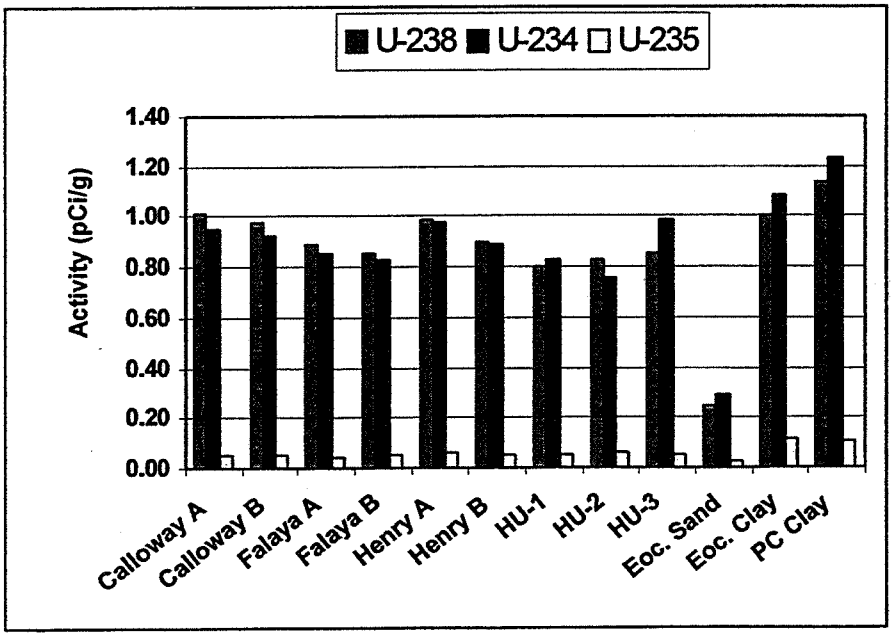


**Fig. 3.1. Mean activities of the uranium isotopes**

**Table 3.1. Background soil statistics for radionuclides**

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95-%ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| | | | | | | **Cs-137** | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 0.104-0.250 | 0.130 | 0.178 | 0.225 | 0.027 | 0.248 | 0.301 | 0.435 |
| Calloway | B | 0.7-3.0 | 5 | 5 | -0.025-0.020 | 0.000 | 0.000 | 0.047 | 0.027 | 0.070 | 0.123 | 0.257 |
| Falaya | A | 0.0-1.0 | 5 | 5 | 0.194-0.262 | 0.178 | 0.225 | 0.272 | 0.027 | 0.295 | 0.348 | 0.482 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 0.025-0.152 | 0.042 | 0.089 | 0.137 | 0.027 | 0.159 | 0.213 | 0.347 |
| Henry | A | 0.0-0.8 | 5 | 5 | 0.231-0.438 | 0.295 | 0.342 | 0.390 | 0.027 | 0.412 | 0.466 | 0.600 |
| Henry | B | 1.0-3.0 | 5 | 5 | -0.029-0.138 | 0.000 | 0.029 | 0.077 | 0.027 | 0.099 | 0.153 | 0.286 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | -0.027-0.025 | 0.000 | 0.000 | 0.037 | 0.020 | 0.034 | 0.069 | 0.139 |
| HU-2 | | 6-21 | 5 | 5 | -0.032-0.001 | 0.000 | 0.000 | 0.037 | 0.020 | 0.034 | 0.069 | 0.140 |
| HU-3 | | 11-24 | 4 | 4 | -0.038-0.004 | 0.000 | 0.000 | 0.042 | 0.022 | 0.031 | 0.069 | 0.143 |
| Eoc. Sand | | 11-26 | 4 | 4 | -0.010-0.010 | 0.000 | 0.000 | 0.046 | 0.025 | 0.028 | 0.069 | 0.147 |
| Eoc. Clay | | 30-32 | 1 | 1 | -0.008-0.008 | 0.000 | 0.000 | 0.079 | 0.042 | 0.000 | 0.069 | 0.175 |
| PC Clay | | 16-28 | 4 | 4 | -0.075-0.014 | 0.000 | 0.000 | 0.040 | 0.021 | 0.033 | 0.069 | 0.141 |
| | | | | | | **Np-237** | | | | | | |
| Calloway | A | 0-0.9 | 5 | 5 | 0.005-0.022 | 0.007 | 0.015 | 0.022 | 0.004 | 0.023 | 0.031 | 0.104 |
| Falaya | A | 0-1.0 | 5 | 5 | 0.011-0.018 | 0.008 | 0.015 | 0.023 | 0.004 | 0.023 | 0.032 | 0.104 |
| Henry | A | 0-0.8 | 5 | 5 | -0.003-0.029 | 0.006 | 0.013 | 0.021 | 0.004 | 0.021 | 0.030 | 0.102 |
| | | | | | | **Pu-238** | | | | | | |
| Calloway | A | 0-0.9 | 5 | 5 | 0.001-0.006 | 0.001 | 0.002 | 0.004 | 0.001 | 0.005 | 0.007 | 0.073 |
| Falaya | A | 0-1.0 | 5 | 5 | 0.000-0.005 | 0.000 | 0.001 | 0.003 | 0.001 | 0.004 | 0.006 | 0.072 |

Table 3.1. (continued)

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95-%ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| Henry | A | 0-0.8 | 5 | 5 | 0.000-0.004 | 0.001 | 0.002 | 0.004 | 0.001 | 0.004 | 0.007 | 0.073 |
| | | | | | | **Pu-239** | | | | | | |
| Calloway | A | 0-0.9 | 5 | 5 | 0.007-0.011 | 0.006 | 0.009 | 0.011 | 0.001 | 0.012 | 0.015 | 0.026 |
| Falaya | A | 0-1.0 | 5 | 5 | 0.005-0.011 | 0.005 | 0.007 | 0.010 | 0.001 | 0.011 | 0.013 | 0.024 |
| Henry | A | 0-0.8 | 5 | 5 | 0.006-0.016 | 0.009 | 0.011 | 0.014 | 0.001 | 0.015 | 0.017 | 0.028 |
| | | | | | | **K-40** | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 13.10-14.30 | 12.976 | 13.550 | 14.124 | 0.331 | 14.659 | 15.286 | 16.337 |
| Calloway | B | 0.7-3.0 | 5 | 5 | 12.40-15.50 | 13.576 | 14.150 | 14.724 | 0.331 | 15.259 | 15.886 | 16.937 |
| Falaya | A | 0.0-1.0 | 5 | 5 | 13.50-14.00 | 13.164 | 13.738 | 14.311 | 0.331 | 14.846 | 15.474 | 16.525 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 13.50-13.80 | 13.064 | 13.638 | 14.211 | 0.331 | 14.746 | 15.374 | 16.425 |
| Henry | A | 0.0-0.8 | 5 | 5 | 11.80-13.50 | 12.326 | 12.900 | 13.474 | 0.331 | 14.009 | 14.636 | 15.687 |
| Henry | B | 1.0-3.0 | 5 | 5 | 12.60-13.50 | 12.476 | 13.050 | 13.624 | 0.331 | 14.159 | 14.786 | 15.837 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | 9.700-13.70 | 11.693 | 11.975 | 12.257 | 0.149 | 12.237 | 12.499 | 13.036 |
| HU-2 | | 6-21 | 5 | 5 | 1.350-8.200 | 5.084 | 5.368 | 5.653 | 0.150 | 5.629 | 5.892 | 6.431 |
| HU-3 | | 11-24 | 4 | 4 | 2.360-5.560 | 3.850 | 4.168 | 4.486 | 0.168 | 4.405 | 4.692 | 5.256 |
| Eoc. Sand | | 11-26 | 4 | 4 | 0.510-2.140 | 0.981 | 1.335 | 1.689 | 0.187 | 1.546 | 1.859 | 2.451 |
| Eoc. Clay | | 30-32 | 1 | 1 | 10.30-10.30 | 9.697 | 10.300 | 10.903 | 0.318 | 10.300 | 10.824 | 11.631 |
| PC Clay | | 16-28 | 4 | 4 | 7.600-9.600 | 8.123 | 8.425 | 8.727 | 0.159 | 8.674 | 8.949 | 9.501 |

Table 3.1. (continued)

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95-%ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| | | | | | | **Ra-226** | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 1.030-1.200 | 1.053 | 1.128 | 1.202 | 0.043 | 1.237 | 1.322 | 1.538 |
| Calloway | B | 0.7-3.0 | 5 | 5 | 1.070-1.320 | 1.110 | 1.185 | 1.260 | 0.043 | 1.294 | 1.379 | 1.595 |
| Falaya | A | 0.0-1.0 | 5 | 5 | 0.930-1.120 | 0.948 | 1.023 | 1.097 | 0.043 | 1.132 | 1.217 | 1.433 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 0.950-1.070 | 0.938 | 1.013 | 1.087 | 0.043 | 1.122 | 1.207 | 1.423 |
| Henry | A | 0.0-0.8 | 5 | 5 | 1.020-1.270 | 1.039 | 1.114 | 1.189 | 0.043 | 1.223 | 1.308 | 1.524 |
| Henry | B | 1.0-3.0 | 5 | 5 | 1.080-1.320 | 1.104 | 1.179 | 1.254 | 0.043 | 1.288 | 1.373 | 1.589 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | 0.491-0.960 | 0.692 | 0.775 | 0.858 | 0.044 | 0.853 | 0.930 | 1.089 |
| HU-2 | | 6-21 | 5 | 5 | 0.479-1.010 | 0.652 | 0.736 | 0.820 | 0.044 | 0.813 | 0.891 | 1.050 |
| HU-3 | | 11-24 | 4 | 4 | 0.740-1.030 | 0.734 | 0.828 | 0.922 | 0.050 | 0.898 | 0.983 | 1.150 |
| Eoc. Sand | | 11-26 | 4 | 4 | 0.172-0.279 | 0.136 | 0.240 | 0.345 | 0.055 | 0.303 | 0.395 | 0.570 |
| Eoc. Clay | | 30-32 | 1 | 1 | 0.920-0.920 | 0.742 | 0.920 | 1.098 | 0.094 | 0.920 | 1.075 | 1.314 |
| PC Clay | | 16-28 | 4 | 4 | 0.710-1.150 | 0.806 | 0.895 | 0.984 | 0.047 | 0.969 | 1.050 | 1.213 |
| | | | | | | **Sr-90** | | | | | | |
| Calloway | A | 0-0.9 | 5 | 5 | -0.280-0.190 | 0.000 | 0.000 | 0.128 | 0.070 | 0.134 | 0.296 | 4.719 |
| Falaya | A | 0-1.0 | 5 | 5 | -0.170-0.220 | 0.000 | 0.000 | 0.128 | 0.070 | 0.134 | 0.296 | 4.719 |
| Henry | A | 0-0.8 | 5 | 5 | -0.080-0.120 | 0.000 | 0.000 | 0.128 | 0.070 | 0.134 | 0.296 | 4.719 |

Table 3.1. (continued)

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95-%ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| | | | | | | Tc-99 | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 0.010-0.440 | 0.000 | 0.204 | 0.723 | 0.299 | 1.274 | 1.839 | 2.728 |
| Calloway | B | 0.7-3.0 | 5 | 5 | 0.000-0.410 | 0.000 | 0.095 | 0.614 | 0.299 | 1.166 | 1.730 | 2.619 |
| Falaya | A | 0.0-1.0 | 5 | 5 | -0.110-0.320 | 0.000 | 0.129 | 0.648 | 0.299 | 1.199 | 1.764 | 2.653 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 0.020-0.350 | 0.000 | 0.266 | 0.786 | 0.299 | 1.337 | 1.902 | 2.791 |
| Henry | A | 0.0-0.8 | 5 | 5 | -0.070-0.470 | 0.000 | 0.121 | 0.641 | 0.299 | 1.192 | 1.757 | 2.646 |
| Henry | B | 1.0-3.0 | 5 | 5 | 0.030-3.050 | 0.306 | 0.825 | 1.344 | 0.299 | 1.896 | 2.460 | 3.349 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | -0.250-0.260 | 0.000 | 0.000 | 0.132 | 0.070 | 0.122 | 0.245 | 0.496 |
| HU-2 | | 6-21 | 5 | 5 | -0.200-0.059 | 0.000 | 0.000 | 0.133 | 0.070 | 0.122 | 0.245 | 0.496 |
| HU-3 | | 11-24 | 4 | 4 | -0.190-0.310 | 0.000 | 0.040 | 0.188 | 0.078 | 0.151 | 0.285 | 0.548 |
| Eoc. Sand | | 11-26 | 4 | 4 | -0.138-0.129 | 0.000 | 0.000 | 0.165 | 0.087 | 0.098 | 0.245 | 0.521 |
| Eoc. Clay | | 30-32 | 1 | 1 | 0.530-0.530 | 0.248 | 0.530 | 0.812 | 0.149 | 0.530 | 0.775 | 1.152 |
| PC Clay | | 16-28 | 4 | 4 | -0.136-0.560 | 0.000 | 0.132 | 0.272 | 0.074 | 0.248 | 0.376 | 0.634 |

Table 3.1. (continued)

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95-%ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| | | | | | | Th-228 | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 1.130-1.250 | 1.116 | 1.210 | 1.304 | 0.054 | 1.384 | 1.487 | 1.669 |
| Calloway | B | 0.7-3.0 | 5 | 5 | 1.180-1.300 | 1.143 | 1.238 | 1.332 | 0.054 | 1.411 | 1.514 | 1.697 |
| Falaya | A | 0.0-1.0 | 5 | 5 | 0.950-1.140 | 0.961 | 1.055 | 1.149 | 0.054 | 1.229 | 1.332 | 1.514 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 1.040-1.200 | 1.023 | 1.117 | 1.212 | 0.054 | 1.291 | 1.394 | 1.577 |
| Henry | A | 0.0-0.8 | 5 | 5 | 1.070-1.420 | 1.082 | 1.176 | 1.270 | 0.054 | 1.350 | 1.453 | 1.635 |
| Henry | B | 1.0-3.0 | 5 | 5 | 0.890-1.250 | 1.006 | 1.100 | 1.194 | 0.054 | 1.274 | 1.377 | 1.559 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | 0.890-1.090 | 0.949 | 0.998 | 1.046 | 0.026 | 1.043 | 1.088 | 1.180 |
| HU-2 | | 6-21 | 5 | 5 | 0.580-1.060 | 0.829 | 0.878 | 0.927 | 0.026 | 0.923 | 0.969 | 1.061 |
| HU-3 | | 11-24 | 4 | 4 | 1.040-1.380 | 1.154 | 1.208 | 1.263 | 0.029 | 1.249 | 1.299 | 1.396 |
| Eoc. Sand | | 11-26 | 4 | 4 | 0.209-0.410 | 0.288 | 0.349 | 0.410 | 0.032 | 0.385 | 0.439 | 0.541 |
| Eoc. Clay | | 30-32 | 1 | 1 | 1.340-1.340 | 1.236 | 1.340 | 1.444 | 0.055 | 1.340 | 1.430 | 1.569 |
| PC Clay | | 16-28 | 4 | 4 | 1.050-1.430 | 1.156 | 1.208 | 1.259 | 0.027 | 1.250 | 1.298 | 1.393 |

Table 3.1. (continued)

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95-%ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| | | | | | | Th-230 | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 1.100-1.260 | 1.127 | 1.199 | 1.271 | 0.041 | 1.326 | 1.406 | 1.553 |
| Calloway | B | 0.7-3.0 | 5 | 5 | 1.130-1.390 | 1.173 | 1.245 | 1.317 | 0.041 | 1.373 | 1.452 | 1.599 |
| Falaya | A | 0.0-1.0 | 5 | 5 | 0.920-1.060 | 0.914 | 0.986 | 1.058 | 0.041 | 1.114 | 1.193 | 1.340 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 0.880-1.060 | 0.917 | 0.989 | 1.061 | 0.041 | 1.116 | 1.196 | 1.343 |
| Henry | A | 0.0-0.8 | 5 | 5 | 1.090-1.280 | 1.092 | 1.164 | 1.236 | 0.041 | 1.291 | 1.371 | 1.518 |
| Henry | B | 1.0-3.0 | 5 | 5 | 1.000-1.250 | 1.022 | 1.094 | 1.166 | 0.041 | 1.221 | 1.301 | 1.448 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | 0.770-1.520 | 1.020 | 1.061 | 1.103 | 0.022 | 1.100 | 1.138 | 1.217 |
| HU-2 | | 6-21 | 5 | 5 | 0.476-0.860 | 0.684 | 0.726 | 0.768 | 0.022 | 0.764 | 0.803 | 0.882 |
| HU-3 | | 11-24 | 4 | 4 | 0.800-1.100 | 0.847 | 0.893 | 0.940 | 0.025 | 0.928 | 0.970 | 1.053 |
| Eoc. Sand | | 11-26 | 4 | 4 | 0.070-0.278 | 0.158 | 0.210 | 0.262 | 0.027 | 0.241 | 0.287 | 0.374 |
| Eoc. Clay | | 30-32 | 1 | 1 | 1.110-1.110 | 1.021 | 1.110 | 1.199 | 0.047 | 1.110 | 1.187 | 1.306 |
| PC Clay | | 16-28 | 4 | 4 | 0.750-1.430 | 0.951 | 0.995 | 1.039 | 0.023 | 1.032 | 1.072 | 1.153 |

Table 3.1. (continued)

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95-%ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| | | | | | | Th-232 | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 1.050-1.280 | 1.063 | 1.148 | 1.232 | 0.049 | 1.291 | 1.385 | 1.570 |
| Calloway | B | 0.7-3.0 | 5 | 5 | 1.100-1.280 | 1.119 | 1.204 | 1.288 | 0.049 | 1.347 | 1.441 | 1.626 |
| Falaya | A | 0.0-1.0 | 5 | 5 | 0.860-1.080 | 0.890 | 0.975 | 1.060 | 0.049 | 1.119 | 1.213 | 1.398 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 0.870-1.070 | 0.905 | 0.990 | 1.075 | 0.049 | 1.134 | 1.228 | 1.413 |
| Henry | A | 0.0-0.8 | 5 | 5 | 0.990-1.260 | 1.017 | 1.101 | 1.186 | 0.049 | 1.245 | 1.339 | 1.524 |
| Henry | B | 1.0-3.0 | 5 | 5 | 0.930-1.190 | 0.977 | 1.061 | 1.146 | 0.049 | 1.205 | 1.299 | 1.484 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | 0.880-1.230 | 0.948 | 1.006 | 1.065 | 0.031 | 1.060 | 1.114 | 1.225 |
| HU-2 | | 6-21 | 5 | 5 | 0.563-0.960 | 0.800 | 0.859 | 0.918 | 0.031 | 0.913 | 0.967 | 1.078 |
| HU-3 | | 11-24 | 4 | 4 | 0.970-1.140 | 1.036 | 1.102 | 1.167 | 0.035 | 1.151 | 1.210 | 1.326 |
| Eoc. Sand | | 11-26 | 4 | 4 | 0.174-0.428 | 0.274 | 0.347 | 0.420 | 0.039 | 0.390 | 0.455 | 0.577 |
| Eoc. Clay | | 30-32 | 1 | 1 | 1.330-1.330 | 1.205 | 1.330 | 1.455 | 0.066 | 1.330 | 1.438 | 1.605 |
| PC Clay | | 16-28 | 4 | 4 | 1.070-1.330 | 1.138 | 1.200 | 1.262 | 0.033 | 1.251 | 1.308 | 1.422 |
| | | | | | | U-234 | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 0.817-1.020 | 0.909 | 0.949 | 0.988 | 0.023 | 0.993 | 1.046 | 2.507 |
| Calloway | B | 0.7-3.0 | 5 | 5 | 0.809-0.966 | 0.882 | 0.922 | 0.962 | 0.023 | 0.966 | 1.020 | 2.480 |
| Falaya | A | 0.0-1.0 | 5 | 5 | 0.808-0.941 | 0.818 | 0.858 | 0.897 | 0.023 | 0.902 | 0.955 | 2.416 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 0.779-0.855 | 0.784 | 0.824 | 0.864 | 0.023 | 0.868 | 0.922 | 2.382 |
| Henry | A | 0.0-0.8 | 5 | 5 | 0.913-1.023 | 0.933 | 0.973 | 1.013 | 0.023 | 1.017 | 1.070 | 2.531 |
| Henry | B | 1.0-3.0 | 5 | 5 | 0.872-0.940 | 0.852 | 0.892 | 0.931 | 0.023 | 0.936 | 0.989 | 2.450 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | 0.750-0.890 | 0.795 | 0.846 | 0.898 | 0.027 | 0.894 | 0.942 | 1.040 |

Table 3.1. (continued)

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95-%ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| HU-2 | | 6-21 | 5 | 5 | 0.513-1.140 | 0.707 | 0.759 | 0.811 | 0.027 | 0.806 | 0.855 | 0.953 |
| HU-3 | | 11-24 | 4 | 4 | 0.770-1.450 | 0.925 | 0.983 | 1.041 | 0.031 | 1.027 | 1.079 | 1.182 |
| Eoc. Sand | | 11-26 | 4 | 4 | 0.125-0.345 | 0.224 | 0.288 | 0.353 | 0.034 | 0.327 | 0.384 | 0.492 |
| Eoc. Clay | | 30-32 | 1 | 1 | 1.080-1.080 | 0.970 | 1.080 | 1.190 | 0.058 | 1.080 | 1.176 | 1.323 |
| PC Clay | | 16-28 | 4 | 4 | 0.970-1.540 | 1.177 | 1.233 | 1.288 | 0.029 | 1.278 | 1.328 | 1.429 |
| | | | | | | U-235 | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 0.022-0.092 | 0.041 | 0.057 | 0.074 | 0.009 | 0.080 | 0.099 | 0.151 |
| Calloway | B | 0.7-3.0 | 5 | 5 | 0.030-0.060 | 0.034 | 0.051 | 0.067 | 0.009 | 0.074 | 0.092 | 0.145 |
| Falaya | A | 0.0-1.0 | 5 | 5 | 0.033-0.064 | 0.030 | 0.046 | 0.063 | 0.009 | 0.069 | 0.088 | 0.140 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 0.038-0.076 | 0.038 | 0.054 | 0.070 | 0.009 | 0.077 | 0.096 | 0.148 |
| Henry | A | 0.0-0.8 | 5 | 5 | 0.031-0.078 | 0.042 | 0.058 | 0.074 | 0.009 | 0.081 | 0.100 | 0.152 |
| Henry | B | 1.0-3.0 | 5 | 5 | 0.042-0.099 | 0.038 | 0.054 | 0.070 | 0.009 | 0.077 | 0.096 | 0.148 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | 0.038-0.103 | 0.054 | 0.070 | 0.085 | 0.008 | 0.084 | 0.099 | 0.128 |
| HU-2 | | 6-21 | 5 | 5 | 0.038-0.090 | 0.042 | 0.058 | 0.074 | 0.008 | 0.073 | 0.087 | 0.117 |
| HU-3 | | 11-24 | 4 | 4 | 0.032-0.066 | 0.034 | 0.052 | 0.069 | 0.009 | 0.065 | 0.081 | 0.112 |
| Eoc. Sand | | 11-26 | 4 | 4 | 0.025-0.032 | 0.010 | 0.030 | 0.049 | 0.010 | 0.041 | 0.059 | 0.092 |
| Eoc. Clay | | 30-32 | 1 | 1 | 0.118-0.118 | 0.085 | 0.118 | 0.151 | 0.018 | 0.118 | 0.147 | 0.192 |
| PC Clay | | 16-28 | 4 | 4 | 0.053-0.152 | 0.091 | 0.107 | 0.124 | 0.009 | 0.121 | 0.136 | 0.167 |

Table 3.1. (continued)

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95-%ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| | | | | | | U-238 | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 0.950-1.058 | 0.959 | 1.012 | 1.066 | 0.031 | 1.103 | 1.163 | 1.281 |
| Calloway | B | 0.7-3.0 | 5 | 5 | 0.905-1.033 | 0.928 | 0.981 | 1.035 | 0.031 | 1.072 | 1.132 | 1.250 |
| Falaya | A | 0.0-1.0 | 5 | 5 | 0.820-0.931 | 0.842 | 0.896 | 0.950 | 0.031 | 0.987 | 1.047 | 1.165 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 0.820-0.923 | 0.800 | 0.854 | 0.908 | 0.031 | 0.945 | 1.005 | 1.123 |
| Henry | A | 0.0-0.8 | 5 | 5 | 0.836-1.100 | 0.933 | 0.987 | 1.040 | 0.031 | 1.078 | 1.137 | 1.255 |
| Henry | B | 1.0-3.0 | 5 | 5 | 0.825-1.007 | 0.842 | 0.896 | 0.950 | 0.031 | 0.987 | 1.047 | 1.165 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | 0.720-0.820 | 0.733 | 0.773 | 0.812 | 0.021 | 0.809 | 0.846 | 0.921 |
| HU-2 | | 6-21 | 5 | 5 | 0.596-1.180 | 0.788 | 0.828 | 0.868 | 0.021 | 0.864 | 0.901 | 0.977 |
| HU-3 | | 11-24 | 4 | 4 | 0.710-1.300 | 0.812 | 0.857 | 0.901 | 0.024 | 0.890 | 0.930 | 1.009 |
| Eoc. Sand | | 11-26 | 4 | 4 | 0.145-0.301 | 0.195 | 0.245 | 0.294 | 0.026 | 0.274 | 0.318 | 0.401 |
| Eoc. Clay | | 30-32 | 1 | 1 | 1.000-1.000 | 0.915 | 1.000 | 1.085 | 0.045 | 1.000 | 1.073 | 1.187 |
| PC Clay | | 16-28 | 4 | 4 | 0.850-1.550 | 1.095 | 1.138 | 1.180 | 0.022 | 1.172 | 1.211 | 1.288 |

Note:
*LCB = Lower confidence boundary, UCB = upper confidence boundary, LTB = lower tolerance boundary, UTB = upper tolerance boundary

**Table 3.2. Background soil statistics for metals**

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95-%ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | mg/kg | | | | | | |
| | | | | | **Beryllium** | | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 0.340-0.550 | 0.441 | 0.488 | 0.534 | 0.027 | 0.566 | 0.618 | 0.723 |
| Calloway | B | 0.7-3.0 | 5 | 5 | 0.380-0.520 | 0.408 | 0.455 | 0.502 | 0.027 | 0.533 | 0.585 | 0.691 |
| Falaya | A | 0.0-1.0 | 5 | 5 | 0.390-0.480 | 0.398 | 0.445 | 0.492 | 0.027 | 0.523 | 0.575 | 0.681 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 0.360-0.480 | 0.384 | 0.431 | 0.478 | 0.027 | 0.509 | 0.561 | 0.667 |
| Henry | A | 0.0-0.8 | 5 | 5 | 0.390-0.460 | 0.368 | 0.415 | 0.462 | 0.027 | 0.493 | 0.545 | 0.651 |
| Henry | B | 1.0-3.0 | 5 | 5 | 0.420-0.570 | 0.453 | 0.500 | 0.547 | 0.027 | 0.578 | 0.630 | 0.736 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | 0.230-0.510 | 0.452 | 0.484 | 0.516 | 0.017 | 0.514 | 0.543 | 0.604 |
| HU-2 | | 6-21 | 5 | 5 | 0.220-0.490 | 0.351 | 0.383 | 0.416 | 0.017 | 0.413 | 0.443 | 0.504 |
| HU-3 | | 11-24 | 4 | 4 | 0.470-1.300 | 0.587 | 0.623 | 0.659 | 0.019 | 0.650 | 0.683 | 0.747 |
| Eoc. Sand | | 11-26 | 4 | 0 | 0.190-0.200 | . | . | . | . | . | . | |
| Eoc. Clay | | 30-32 | 1 | 1 | 0.220-0.220 | 0.152 | 0.220 | 0.288 | 0.036 | 0.220 | 0.279 | 0.371 |
| PC Clay | | 16-28 | 4 | 4 | 0.910-1.600 | 1.126 | 1.160 | 1.194 | 0.018 | 1.188 | 1.219 | 1.282 |

Table 3.2. (continued)

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean 95% LCB[a] | Mean | Mean 95% UCB[a] | Std. Error Mean | 95-%ile 95% LTB[a] | 95-%ile | 95-%ile 95% UTB[t] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | mg/kg | | | | | | |
| | | | | | **Thallium** | | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 2 | 0.190-0.200 | . | 0.189 | . | . | . | | |
| Calloway | B | 0.7-3.0 | 5 | 5 | 0.210-0.300 | 0.221 | 0.269 | 0.316 | 0.020 | 0.253 | 0.326 | 0.400 |
| Falaya | A | 0.0-1.0 | 5 | 2 | 0.180-0.200 | 0.139 | 0.180 | 0.222 | 0.018 | 0.168 | 0.207 | 0.246 |
| Falaya | B | 0.7-1.6 | 5 | 3 | 0.190-0.240 | 0.154 | 0.202 | 0.250 | 0.020 | 0.183 | 0.250 | 0.316 |
| Henry | A | 0.0-0.8 | 5 | 0 | 0.190-0.200 | . | . | . | . | . | . | . |
| Henry | B | 1.0-3.0 | 5 | 4 | 0.190-0.230 | 0.187 | 0.214 | 0.241 | 0.011 | 0.203 | 0.245 | 0.287 |
| HU-1 | Loess | 2.5-12 | 8 | 1 | 0.190-0.200 | 0.159 | 0.184 | 0.208 | 0.013 | 0.186 | 0.201 | 0.216 |
| HU-2 | | 6-21 | 5 | 0 | 0.180-0.200 | . | . | . | . | . | . | . |
| HU-3 | | 11-24 | 4 | 2 | 0.190-0.210 | 0.173 | 0.197 | 0.221 | 0.010 | 0.187 | 0.221 | 0.255 |
| Eoc. Sand | | 11-26 | 4 | 0 | 0.190-0.200 | . | . | . | . | . | . | . |
| Eoc. Clay | | 30-32 | 1 | 0 | 0.190-0.190 | . | . | . | . | . | . | . |
| PC Clay | | 16-28 | 4 | 1 | 0.190-0.270 | 0.000 | 0.135 | 0.412 | 0.118 | 0.056 | 0.299 | 0.542 |
| | | | | | **Total Uranium** | | | | | | | |
| Calloway | A | 0.0-0.9 | 5 | 5 | 3.777-4.207 | 3.812 | 4.025 | 4.239 | 0.123 | 4.388 | 4.625 | 5.095 |
| Calloway | B | 0.7-3.0 | 5 | 5 | 3.598-4.107 | 3.688 | 3.902 | 4.116 | 0.123 | 4.264 | 4.502 | 4.972 |
| Falaya | A | 0.0-1.0 | 5 | 5 | 3.260-3.702 | 3.349 | 3.563 | 3.777 | 0.123 | 3.925 | 4.163 | 4.633 |
| Falaya | B | 0.7-1.6 | 5 | 5 | 3.260-3.670 | 3.182 | 3.396 | 3.609 | 0.123 | 3.758 | 3.995 | 4.465 |
| Henry | A | 0.0-0.8 | 5 | 5 | 3.324-4.374 | 3.709 | 3.923 | 4.136 | 0.123 | 4.285 | 4.522 | 4.992 |
| Henry | B | 1.0-3.0 | 5 | 5 | 3.280-4.004 | 3.35 | 3.564 | 3.777 | 0.123 | 3.926 | 4.163 | 4.633 |
| HU-1 | Loess | 2.5-12 | 8 | 8 | 2.863-3.260 | 2.914 | 3.072 | 3.229 | 0.083 | 3.218 | 3.363 | 3.663 |
| HU-2 | | 6-21 | 4 | 4 | 2.370-4.692 | 3.133 | 3.291 | 3.449 | 0.084 | 3.436 | 3.583 | 3.883 |

**Table 3.2. (continued)**

| Soil | Horizon | Depth (ft.) | N | Det. | Range | Mean 95% LCB[a] | Mean | Mean 95% UCB[a] | Std. Error Mean | 95-%ile 95% LTB[a] | 95-%ile | 95-%ile 95% UTB[1] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | mg/kg | | | | | | |
| HU-3 | | 11-24 | 4 | 4 | 2.823-5.169 | 3.229 | 3.406 | 3.583 | 0.094 | 3.538 | 3.698 | 4.012 |
| Eoc. Sand | | 11-26 | 4 | 4 | 0.577-1.197 | 0.777 | 0.974 | 1.171 | 0.104 | 1.091 | 1.265 | 1.595 |
| Eoc. Clay | | 30-32 | 1 | 1 | 3.976-3.976 | 3.64 | 3.976 | 4.312 | 0.177 | 3.976 | 4.268 | 4.718 |
| PC Clay | | 16-28 | 4 | 4 | 3.380-6.163 | 4.355 | 4.523 | 4.691 | 0.089 | 4.661 | 4.815 | 5.122 |
| **Antimony** | | | | | | | | | | | | |
| All 56 samples were below detection levels (0.19 - 0.20 mg/kg) | | | | | | | | | | | | |
| **Cadmium** | | | | | | | | | | | | |
| All 56 samples were below detection levels (0.19 - 0.20 mg/kg) | | | | | | | | | | | | |

Note:
[*]LCB = Lower confidence boundary, UCB = upper confidence boundary, LTB = lower tolerance boundary, UTB = upper tolerance boundary

**Table 3.3. Activities of radionuclides in A and B soil horizons (Calloway, Falaya, and Henry soils)**

| Radio-nuclide | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95%-ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| Cs-137 | A | 0-1 | 15 | 15 | 0.104-0.438 | 0.221 | 0.248 | 0.276 | 0.016 | 0.328 | 0.372 | 0.494 |
| | B | 0.7-3 | 15 | 15 | -0.029-0.152 | 0.010 | 0.037 | 0.065 | 0.016 | 0.117 | 0.161 | 0.283 |
| Np-237 | A | 0-1 | 15 | 15 | -0.003-0.029 | 0.010 | 0.014 | 0.019 | 0.002 | 0.023 | 0.031 | 0.102 |
| K-40 | A | 0-1 | 15 | 15 | 11.80-14.30 | 13.064 | 13.396 | 13.727 | 0.191 | 14.647 | 15.132 | 16.031 |
| | B | 0.7-3 | 15 | 15 | 12.40-15.50 | 13.281 | 13.612 | 13.944 | 0.191 | 14.864 | 15.349 | 16.248 |
| Pu-238 | A | 0-1 | 15 | 15 | 0.000-0.006 | 0.001 | 0.002 | 0.003 | 0.000 | 0.004 | 0.006 | 0.073 |
| Pu-239 | A | 0-1 | 15 | 15 | 0.005-0.016 | 0.008 | 0.009 | 0.010 | 0.001 | 0.013 | 0.015 | 0.025 |
| Ra-226 | A | 0-1 | 15 | 15 | 0.930-1.270 | 1.045 | 1.088 | 1.131 | 0.025 | 1.213 | 1.282 | 1.481 |
| | B | 0.7-3 | 15 | 15 | 0.950-1.320 | 1.082 | 1.125 | 1.169 | 0.025 | 1.250 | 1.319 | 1.518 |
| Sr-90 | A | 0-1 | 15 | 15 | -0.280-0.220 | 0.000 | 0.000 | 0.074 | 0.040 | 0.146 | 0.296 | 4.719 |
| Tc-99 | A | 0-1 | 15 | 15 | -0.110-0.470 | 0.000 | 0.151 | 0.451 | 0.173 | 1.355 | 1.787 | 2.535 |
| | B | 0.7-3 | 15 | 15 | 0.000-3.050 | 0.096 | 0.395 | 0.695 | 0.173 | 1.599 | 2.031 | 2.779 |
| Th-228 | A | 0-1 | 15 | 15 | 0.950-1.420 | 1.093 | 1.147 | 1.201 | 0.031 | 1.343 | 1.424 | 1.582 |
| | B | 0.7-3 | 15 | 15 | 0.890-1.300 | 1.097 | 1.152 | 1.206 | 0.031 | 1.348 | 1.429 | 1.586 |
| Th-230 | A | 0-1 | 15 | 15 | 0.920-1.280 | 1.075 | 1.116 | 1.158 | 0.024 | 1.261 | 1.323 | 1.452 |
| | B | 0.7-3 | 15 | 15 | 0.880-1.390 | 1.068 | 1.109 | 1.151 | 0.024 | 1.254 | 1.316 | 1.445 |

Table 3.3. (continued)

| Radio-nuclide | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95%-ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| Th-232 | A | 0-1 | 15 | 15 | 0.860-1.280 | 1.026 | 1.075 | 1.123 | 0.028 | 1.237 | 1.312 | 1.476 |
| | B | 0.7-3 | 15 | 15 | 0.870-1.280 | 1.036 | 1.085 | 1.134 | 0.028 | 1.248 | 1.323 | 1.487 |
| U-234 | A | 0-1 | 15 | 15 | 0.808-1.023 | 0.903 | 0.926 | 0.949 | 0.013 | 0.974 | 1.024 | 2.485 |
| | B | 0.7-3 | 15 | 15 | 0.779-0.966 | 0.856 | 0.879 | 0.902 | 0.013 | 0.927 | 0.977 | 2.438 |
| U-235 | A | 0-1 | 15 | 15 | 0.022-0.092 | 0.044 | 0.054 | 0.063 | 0.005 | 0.080 | 0.095 | 0.144 |
| | B | 0.7-3 | 15 | 15 | 0.030-0.099 | 0.043 | 0.053 | 0.062 | 0.005 | 0.079 | 0.095 | 0.143 |
| U-238 | A | 0-1 | 15 | 15 | 0.820-1.100 | 0.934 | 0.965 | 0.996 | 0.018 | 1.068 | 1.116 | 1.221 |
| | B | 0.7-3 | 15 | 15 | 0.820-1.033 | 0.879 | 0.911 | 0.942 | 0.018 | 1.014 | 1.061 | 1.166 |

Note:
*LCB = Lower confidence boundary, UCB = upper confidence boundary, LTB = lower tolerance boundary, UTB = upper tolerance boundary

**Table 3.4. Concentration of metals in A and B soil horizons (Calloway, Falaya, and Henry soils)**

| Metal | Horizon | Depth (ft.) | N | Det. | Range | Mean | | | | 95%-ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | Std. Error Mean | 95% LTB* | | 95% UTB* |
| | | | | | | | | mg/kg | | | | |
| Be | A | 0-1 | 15 | 15 | 0.340-0.550 | 0.422 | 0.449 | 0.476 | 0.016 | 0.538 | 0.579 | 0.673 |
| | B | 0.7-3 | 15 | 15 | 0.360-0.570 | 0.435 | 0.462 | 0.489 | 0.016 | 0.551 | 0.592 | 0.686 |
| Tl | A | 0-1 | 15 | 4 | 0.180-0.200 | 0.169 | 0.182 | 0.195 | 0.007 | 0.189 | 0.199 | 0.209 |
| | B | 0.7-3 | 15 | 12 | 0.190-0.300 | 0.202 | 0.226 | 0.251 | 0.014 | 0.260 | 0.298 | 0.336 |
| Total uranium | A | 0-1 | 15 | 15 | 3.260-4.374 | 3.714 | 3.837 | 3.960 | 0.071 | 4.248 | 4.437 | 4.853 |
| | B | 0.7-3 | 15 | 15 | 3.260-4.107 | 3.497 | 3.620 | 3.744 | 0.071 | 4.031 | 4.220 | 4.637 |

Note:
*LCB = Lower confidence boundary, UCB = upper confidence boundary, LTB = lower tolerance boundary, UTB = upper tolerance boundary

**Table 3.5 Activities of radionuclides in three soils (includes A and B soil horizons)**

| Radio-nuclide | Soil | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95%-ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| Cs-137 | Calloway | 0-3 | 10 | 10 | -0.025-0.250 | 0.052 | 0.085 | 0.119 | 0.019 | 0.163 | 0.209 | 0.334 |
| | Falaya | 0-1.6 | 10 | 10 | 0.025-0.262 | 0.124 | 0.157 | 0.191 | 0.019 | 0.234 | 0.281 | 0.406 |
| | Henry | 0-3 | 10 | 10 | -0.029-0.438 | 0.152 | 0.186 | 0.219 | 0.019 | 0.263 | 0.309 | 0.435 |
| Np-237 | Calloway | 0-0.9 | 5 | 5 | 0.005-0.022 | 0.007 | 0.015 | 0.022 | 0.004 | 0.023 | 0.031 | 0.104 |
| | Falaya | 0-1 | 5 | 5 | 0.011-0.018 | 0.008 | 0.015 | 0.023 | 0.004 | 0.023 | 0.032 | 0.104 |
| | Henry | 0-0.8 | 5 | 5 | -0.003-0.029 | 0.006 | 0.013 | 0.021 | 0.004 | 0.021 | 0.030 | 0.102 |
| Pu-238 | Calloway | 0-0.9 | 5 | 5 | 0.001-0.006 | 0.001 | 0.002 | 0.004 | 0.001 | 0.005 | 0.007 | 0.073 |
| | Falaya | 0-1 | 5 | 5 | 0.000-0.005 | 0.000 | 0.001 | 0.003 | 0.001 | 0.004 | 0.006 | 0.072 |
| | Henry | 0-0.8 | 5 | 5 | 0.000-0.004 | 0.001 | 0.002 | 0.004 | 0.001 | 0.004 | 0.007 | 0.073 |
| Pu-239 | Calloway | 0-0.9 | 5 | 5 | 0.007-0.011 | 0.006 | 0.009 | 0.011 | 0.001 | 0.012 | 0.015 | 0.026 |
| | Falaya | 0-1 | 5 | 5 | 0.005-0.011 | 0.005 | 0.007 | 0.010 | 0.001 | 0.011 | 0.013 | 0.024 |
| | Henry | 0-0.8 | 5 | 5 | 0.006-0.016 | 0.009 | 0.011 | 0.014 | 0.001 | 0.015 | 0.017 | 0.028 |
| K-40 | Calloway | 0-3 | 10 | 10 | 12.40-15.50 | 13.444 | 13.850 | 14.256 | 0.234 | 15.063 | 15.586 | 16.526 |
| | Falaya | 0-1.6 | 10 | 10 | 13.50-14.00 | 13.282 | 13.688 | 14.093 | 0.234 | 14.901 | 15.424 | 16.364 |
| | Henry | 0-3 | 10 | 10 | 11.80-13.50 | 12.569 | 12.975 | 13.381 | 0.234 | 14.188 | 14.711 | 15.651 |
| Ra-226 | Calloway | 0-3 | 10 | 10 | 1.030-1.320 | 1.103 | 1.156 | 1.209 | 0.031 | 1.277 | 1.350 | 1.554 |
| | Falaya | 0-1.6 | 10 | 10 | 0.930-1.120 | 0.965 | 1.018 | 1.070 | 0.031 | 1.138 | 1.212 | 1.415 |
| | Henry | 0-3 | 10 | 10 | 1.020-1.320 | 1.093 | 1.146 | 1.199 | 0.031 | 1.267 | 1.340 | 1.544 |
| Sr-90 | Calloway | 0-0.9 | 5 | 5 | -0.280-0.190 | 0.000 | 0.000 | 0.128 | 0.070 | 0.134 | 0.296 | 4.719 |
| | Falaya | 0-1 | 5 | 5 | -0.170-0.220 | 0.000 | 0.000 | 0.128 | 0.070 | 0.134 | 0.296 | 4.719 |
| | Henry | 0-0.8 | 5 | 5 | -0.080-0.120 | 0.000 | 0.000 | 0.128 | 0.070 | 0.134 | 0.296 | 4.719 |
| Tc-99 | Calloway | 0-3 | 10 | 10 | 0.000-0.440 | 0.000 | 0.149 | 0.517 | 0.212 | 1.317 | 1.785 | 2.571 |
| | Falaya | 0-1.6 | 10 | 10 | -0.110-0.350 | 0.000 | 0.198 | 0.565 | 0.212 | 1.366 | 1.833 | 2.620 |

Table 3.5. (continued)

| Radio-nuclide | Soil | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95%-ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | pCi/g | | | | | | |
| | Henry | 0-3 | 10 | 10 | -0.070-3.050 | 0.106 | 0.473 | 0.840 | 0.212 | 1.641 | 2.108 | 2.895 |
| Th-228 | Calloway | 0-3 | 10 | 10 | 1.130-1.300 | 1.157 | 1.224 | 1.290 | 0.038 | 1.414 | 1.501 | 1.665 |
| | Falaya | 0-1.6 | 10 | 10 | 0.950-1.200 | 1.020 | 1.086 | 1.153 | 0.038 | 1.276 | 1.363 | 1.527 |
| | Henry | 0-3 | 10 | 10 | 0.890-1.420 | 1.072 | 1.138 | 1.205 | 0.038 | 1.328 | 1.415 | 1.579 |
| Th-230 | Calloway | 0-3 | 10 | 10 | 1.100-1.390 | 1.171 | 1.222 | 1.273 | 0.029 | 1.362 | 1.429 | 1.562 |
| | Falaya | 0-1.6 | 10 | 10 | 0.880-1.060 | 0.937 | 0.988 | 1.038 | 0.029 | 1.127 | 1.194 | 1.328 |
| | Henry | 0-3 | 10 | 10 | 1.000-1.280 | 1.078 | 1.129 | 1.180 | 0.029 | 1.269 | 1.336 | 1.469 |
| Th-232 | Calloway | 0-3 | 10 | 10 | 1.050-1.280 | 1.116 | 1.176 | 1.235 | 0.034 | 1.333 | 1.413 | 1.583 |
| | Falaya | 0-1.6 | 10 | 10 | 0.860-1.080 | 0.923 | 0.983 | 1.042 | 0.034 | 1.140 | 1.220 | 1.390 |
| | Henry | 0-3 | 10 | 10 | 0.930-1.260 | 1.021 | 1.081 | 1.141 | 0.034 | 1.239 | 1.319 | 1.488 |
| U-234 | Calloway | 0-3 | 10 | 10 | 0.809-1.020 | 0.907 | 0.935 | 0.963 | 0.016 | 0.982 | 1.033 | 2.494 |
| | Falaya | 0-1.6 | 10 | 10 | 0.779-0.941 | 0.813 | 0.841 | 0.869 | 0.016 | 0.888 | 0.939 | 2.399 |
| | Henry | 0-3 | 10 | 10 | 0.872-1.023 | 0.904 | 0.932 | 0.960 | 0.016 | 0.979 | 1.030 | 2.491 |
| U-235 | Calloway | 0-3 | 10 | 10 | 0.022-0.092 | 0.042 | 0.054 | 0.066 | 0.007 | 0.079 | 0.096 | 0.145 |
| | Falaya | 0-1.6 | 10 | 10 | 0.033-0.076 | 0.039 | 0.050 | 0.062 | 0.007 | 0.076 | 0.092 | 0.141 |
| | Henry | 0-3 | 10 | 10 | 0.031-0.099 | 0.044 | 0.056 | 0.068 | 0.007 | 0.081 | 0.098 | 0.147 |
| U-238 | Calloway | 0-3 | 10 | 10 | 0.905-1.058 | 0.959 | 0.997 | 1.035 | 0.022 | 1.097 | 1.148 | 1.256 |
| | Falaya | 0-1.6 | 10 | 10 | 0.820-0.931 | 0.837 | 0.875 | 0.913 | 0.022 | 0.975 | 1.026 | 1.134 |
| | Henry | 0-3 | 10 | 10 | 0.825-1.100 | 0.903 | 0.941 | 0.979 | 0.022 | 1.041 | 1.092 | 1.200 |

Note:
*LCB = Lower confidence boundary, UCB = upper confidence boundary, LTB = lower tolerance boundary, UTB = upper tolerance boundary

**Table 3.6 Concentrations of metals in three soils (includes A and B soil horizons)**

| Metal | Soil | Depth (ft.) | N | Det. | Range | Mean | | | Std. Error Mean | 95%-ile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 95% LCB* | | 95% UCB* | | 95% LTB* | | 95% UTB* |
| | | | | | | mg/kg | | | | | | |
| Be | Calloway | 0-3 | 10 | 10 | 0.340-0.550 | 0.438 | 0.471 | 0.504 | 0.019 | 0.557 | 0.601 | 0.698 |
| | Falaya | 0-1.6 | 10 | 10 | 0.360-0.480 | 0.405 | 0.438 | 0.471 | 0.019 | 0.524 | 0.568 | 0.665 |
| | Henry | 0-3 | 10 | 10 | 0.390-0.570 | 0.424 | 0.458 | 0.491 | 0.019 | 0.543 | 0.588 | 0.685 |
| Tl | Calloway | 0-3 | 10 | 7 | 0.190-0.300 | 0.168 | 0.216 | 0.264 | 0.025 | 0.247 | 0.319 | 0.390 |
| | Falaya | 0-1.6 | 10 | 5 | 0.180-0.240 | 0.153 | 0.185 | 0.217 | 0.017 | 0.199 | 0.238 | 0.276 |
| | Henry | 0-3 | 10 | 4 | 0.190-0.230 | 0.155 | 0.188 | 0.221 | 0.017 | 0.201 | 0.241 | 0.281 |
| Total Uranium | Calloway | 0-3 | 10 | 10 | 3.598-4.207 | 3.813 | 3.964 | 4.115 | 0.087 | 4.362 | 4.563 | 4.994 |
| | Falaya | 0-1.6 | 10 | 10 | 3.260-3.702 | 3.328 | 3.479 | 3.631 | 0.087 | 3.877 | 4.079 | 4.510 |
| | Henry | 0-3 | 10 | 10 | 3.280-4.374 | 3.592 | 3.743 | 3.894 | 0.087 | 4.141 | 4.343 | 4.773 |

Note:
*LCB = Lower confidence boundary, UCB = upper confidence boundary, LTB = lower tolerance boundary, UTB = upper tolerance boundary

However, with respect to activity, because of the very high specific activity ($6.13\times10^9$ pCi/$g_{U-234}$ as compared to $3.3\times10^5$ pCi/$g_{U-238}$), $^{234}U$ actually contributes slightly more on an activity basis than $^{238}U$ (49.60, 48.13, and 2.27% respectively, for $^{234}U$, $^{238}U$, and $^{235}U$). The natural activity ratio of $^{234}U/^{238}U$ is 1.03. The mean value for the ratio of $^{234}U/^{238}U$ in the surface soils (A and B horizons of the three soils) was 0.964 indicating a depletion of $^{234}U$ as compared to $^{238}U$. These activity ratios were determined using published mass values and specific activities for each isotope. The theoretical natural activity ratio for $^{234}U/^{238}U$ is 1.00 because all $^{234}U$ is derived from $^{238}U$. The measured mean value for the ratio of $^{234}U/^{238}U$ in the surface soils was 0.964 suggesting a depletion of $^{234}U$ as compared to $^{238}U$. However, this ratio of 0.964 most likely represents sample variability due to limited sample size and uncertainties in sample measurements.

The same ratio for the subsurface horizons (HU-2 and lower) was 1.08 indicating that the lower horizons were slightly enriched when compared to theoretical natural partitioning of activity of the two isotopes. This might be expected if surface soils had a preferential leaching mechanism, such as atomic recoil of $^{234m}Pa$ in to the soil spaces, leading to transport and absorption of $^{234}U$ to the deeper layers. Therefore, the $^{235}U$ to $^{238}U$ ratios were used as an indicator to confirm whether natural uranium existed in the soils.

For $^{235}U/^{238}U$, the natural ratio is 0.047. The mean ratio observed in the surface soils, using alpha spectrometry, was 0.057, and in the deeper horizons (HU-2 and lower) the mean ratio was 0.093. These values might suggest enrichment of $^{235}U$ as compared to $^{238}U$; however, it is important to note that the limited sample size and uncertainties in sample measurements may contribute to the apparent relationship. For example, data to be presented later in the report (Sect. 3.8) suggest that analyses of $^{235}U$ by alpha spectrometry as compared to analyses by NAA are less precise when estimating $^{235}U$ concentration (Fig. 3.15). Therefore, NAA results, which are considered a more precise measure of $^{235}U$ concentrations, were used to confirm whether enriched uranium was present or not present. These results strongly indicated that enriched uranium was not present in the samples. It was concluded that measurement uncertainties in the alpha spectometry results were responsible for the discrepancy. Therefore, in some cases,, it may be more appropriate to calculate a $^{235}U$ concentration from a $^{238}U$ value than using a $^{235}U$ result determined by alpha spectometry.

Another way to inspect the activity distribution of the uranium isotopes is to compare the distributions of their activity in the samples to the theoretical natural isotopic distribution of uranium. This is done by plotting the distribution of uranium isotopic activities measured in the soils and geologic media on triangular coordinates relative to the theoretical distribution of their activities in naturally occurring uranium (see Fig. 3.2). Error associated in analytical determinations as well as variance in population densities in uranium isotopic activities preclude a measurement identical to the theoretical natural isotopic distribution for all samples analyzed; however, this database showed relatively few outliers from the theoretical.

Total uranium concentration in surface soils (A and B horizons of the three soil series) ranged from 3.3 to 4.4 mg/kg (see Fig. 3.3). These values appear to be slightly higher than those cited in Appendix A of DOE (1996b). Values for uranium in Appendix A were those measured in the "south" and "west" sampling sites at the PGDP over the years from 1975 to 1993 (see Fig. 3.4). The mean value for uranium over these years was 2.65 mg/kg; however, the greatest difference between the two data sets is the variability. For example, uranium concentrations at the "south" and "west" sampling sites ranged from 0.7 to 5.0 mg/kg over the years from 1975 to 1993. The highest values were recorded from 1975 through 1982 (mean of 3.65 mg/kg) with lower values from 1983 through 1993 (mean of 1.90 mg/kg). The lower variability of the new data reflects compositing and perhaps changes in analytical procedures.

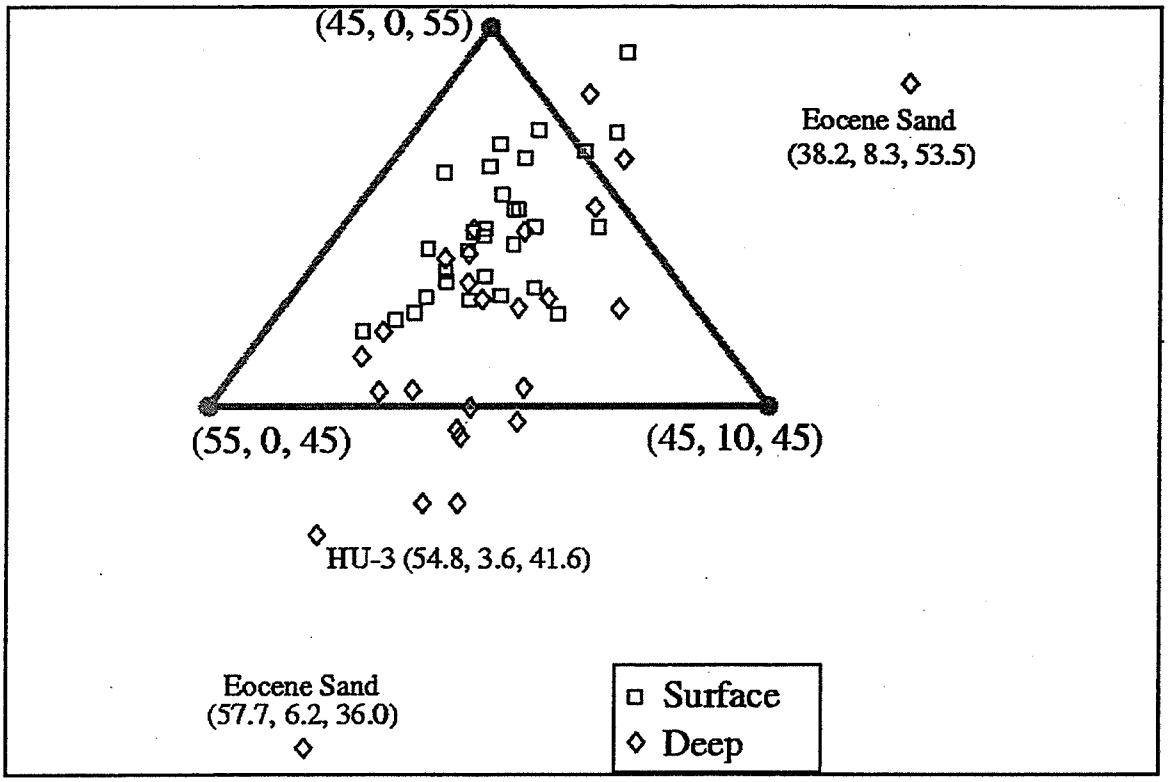


**Fig. 3.2. Distribution of $^{234}U$, $^{235}U$, and $^{238}U$ activities measured in surface soils and deep geologic media. Points are two-dimensional weighted averages of theoretical points for pure isotopes (see Appendix G, Sect. G.4).**

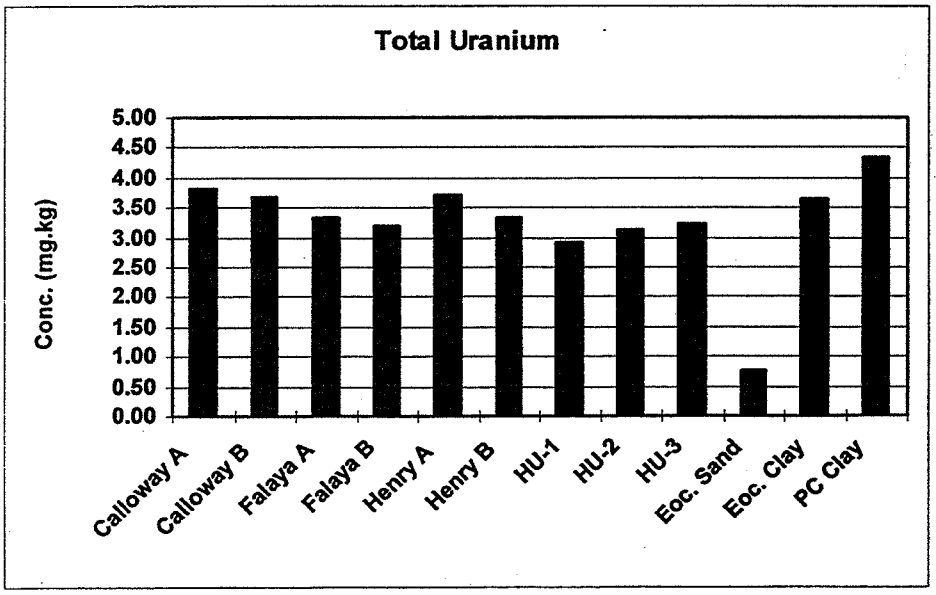


**Fig. 3.3 Concentrations of uranium measured in surface soils and hydrologic units.**

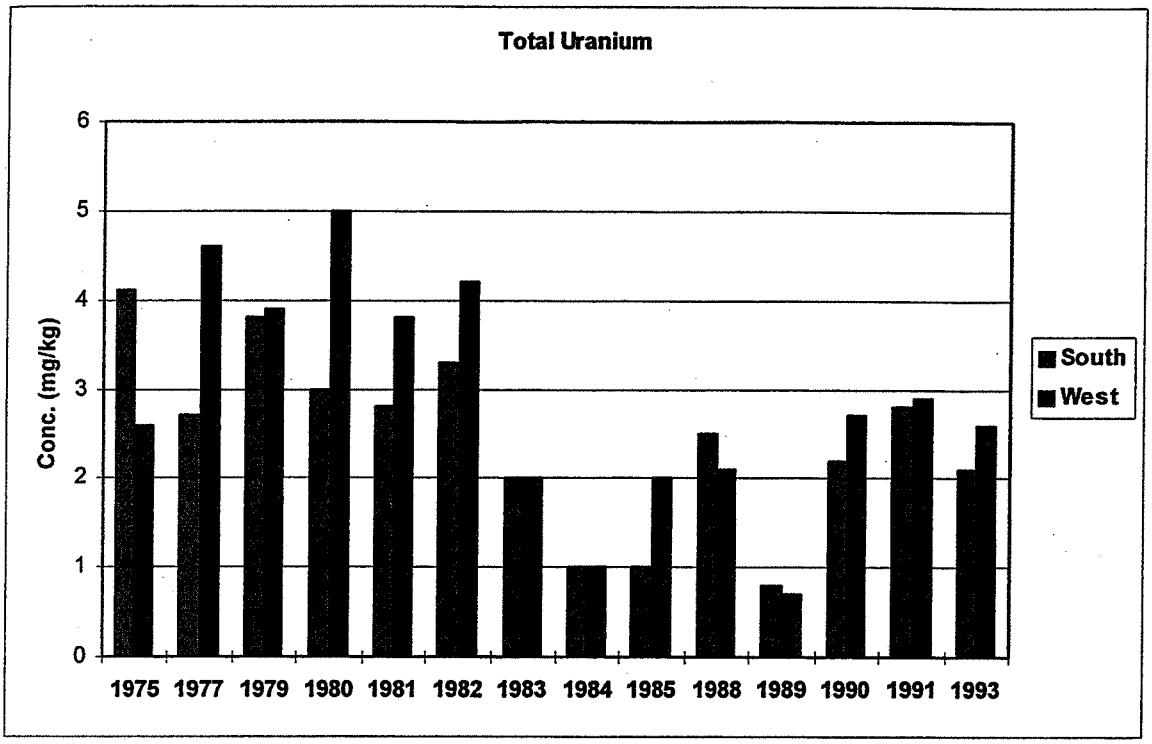


**Fig. 3.4. Uranium concentrations in background locations from 1975 to 1993 (south and west sites as reported in Appendix A, DOE 1996b).**

## 3.2 DISTRIBUTION AND ACTIVITIES OF THORIUM ISOTOPES

The activities of three thorium isotopes ($^{228}$Th, $^{230}$Th, and $^{232}$Th) were determined using alpha-spectroscopy. Thorium-232 was also determined using ICP-MS and NAA methods of analyses. Comparisons among differences and similarities in activities are discussed in Sect. 3.8, Comparisons Between Methods of Analyses. Activities of the thorium isotopes ranged from as low as 0.2 to 0.4 pCi/g in the Eocene sands to approximately 1.2 pCi/g in the single sample of Eocene clay. Typical activities ranged from approximately 0.8 to 1.2 pCi/g (see Fig. 3.5) with a pattern across soils and deep geologic media very similar to that illustrated in Fig. 3.1 for the uranium isotopes.

The activities of $^{228}$Th and $^{232}$Th should be equivalent since both isotopes decay as a result of the thorium radioactive decay series (see Table 3.7). Therefore, the two should be in secular equilibrium; that is, the activities of each should be equivalent as $^{228}$Th is a daughter product of $^{232}$Th with two relatively short-life radioactive isotopes ($^{228}$Ra and $^{228}$Ac) between the two (Table 3.7). This appears to be the case as activity ratios of $^{228}$Th/$^{232}$Th across all the soils and geologic media generally ranged between 1.0 and 1.1 indicating secular equilibrium within the samples. One would expect secular equilibrium in the activities of $^{228}$Th and $^{232}$Th in that the relatively short half-lives of $^{228}$Ra, $^{228}$Ac, and $^{228}$Th would not allow for much differentiation in distribution into the deep portions of the soil profiles even if one of the elements were preferentially leached during soil weathering processes.

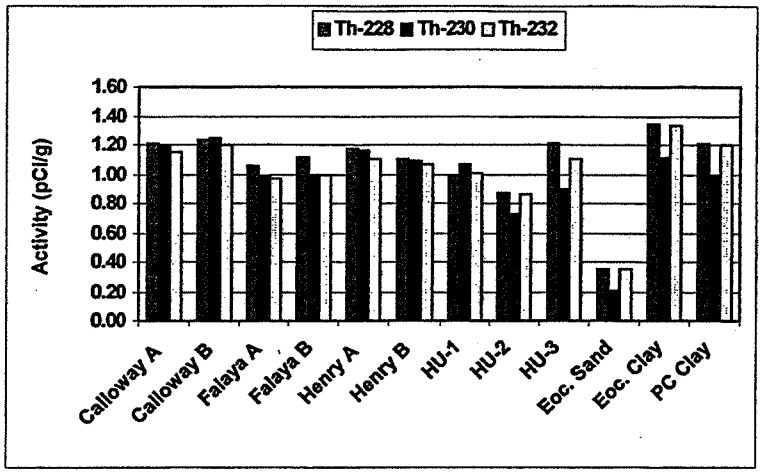


**Fig. 3.5. Mean activities of thorium isotopes.**

**Table 3.7. Radioactive series**

| Thorium series | | Uranium Series | | Actinium Series | |
|---|---|---|---|---|---|
| $^{232}Th$ | | $^{238}U$ | | $^{235}U$ | |
| α ↓ | $1.39\times10^{10}$ y | α ↓ | $4.5\times10^{9}$ y | α ↓ | $7.1\times10^{8}$ y |
| $^{228}Ra$ | | $^{234}Th$ | | $^{231}Th$ | |
| β ↓ | 6.7 y | β ↓ | 24.1 d | β ↓ | 24.6 h |
| $^{228}Ac$ | | $^{234}Pa$ | | $^{231}Pa$ | |
| β ↓ | 6.13 h | β ↓ | 1.14 m | α ↓ | $3.2\times10^{4}$ y |
| $^{228}Th$ | | $^{234}U$ | | $^{227}Ac$ | |
| α ↓ | 1.9 y | α ↓ | $2.3\times10^{5}$ y | αβ ↓ | 21.7 y |
| $^{224}Ra$ | | $^{230}Th$ | | $^{227}Th$ | |
| α ↓ | 3.64 d | α ↓ | $8.0\times10^{4}$ y | αβ ↓ | 18.9 d |
| $^{220}Rn$ | | $^{226}Ra$ | | $^{223}Ra$ | |
| α ↓ | 54.5 y | α ↓ | $1.6\times10^{3}$ y | α ↓ | 11.2 d |
| A variety of short-lived isotopes (Po, Pb, At, Tl, and Bi) | | $^{222}Rn$ | | $^{219}Rn$ | |
| ↓ | | α ↓ | 3.82 d | α ↓ | 3.92 s |
| $^{208}Pb$ | | A variety of short-lived isotopes (Po, Pb, At, Tl, and Bi) | | A variety of short-lived isotopes (Po, Pb, At, Tl, and Bi) | |
| | | ↓ | | ↓ | |
| | | $^{206}Pb$ | | $^{207}Pb$ | |

## 3.3 EVIDENCE OF PREFERENTIAL LEACHING

If preferential leaching had occurred (e.g., if the weathering and leaching of uranium, thorium and radium isotopes from the mineralogical phases differed) one would have a greater probability of detecting such an observation by measuring the activities of uranium ($^{238}$U), thorium ($^{230}$Th), and radium ($^{226}$Ra) of the uranium series. Note in Table 3.7 the much longer half-lives of the intermediate isotopes between $^{238}$U and $^{226}$Ra; namely the $^{234}$U, $^{230}$Th, and $^{226}$Ra. In this investigation, $^{226}$Ra activities were estimated from the activities of $^{214}$Bi using gamma spectroscopy. The longest half-life isotope between $^{214}$Bi and $^{226}$Ra is $^{222}$Rn, with a 3.82 day half-life (see Table 3.7). If one assumes secular equilibrium and containment of the $^{222}$Rn, $^{214}$Bi activities should be a good approximation of $^{226}$Ra activity. It should be noted that some of the $^{222}$Rn may have been lost during sample preparation; however, sufficient time should have elapsed between sample preparation and analysis to make $^{214}$Bi a good approximation for $^{226}$Ra estimation.

The distribution pattern of the $^{234}$U/$^{238}$U, $^{230}$Th/$^{238}$U, and $^{226}$Ra/$^{238}$U activity ratios within the A and B horizons of the three soils appear to be nearly identical indicating little differential in leaching within the A and B horizons (see Fig. 3.6). However, for both horizons in all three soils, the activity ratio of $^{226}$Ra/$^{238}$U is greater than one indicating preferential leaching of uranium to radium in these horizons. Note the considerably lower ratios of $^{226}$Ra/$^{238}$U in the loess (HU-1 horizon, samples taken at depths generally ranging from 3 to 10 ft). There appears to be a decrease in the $^{226}$Ra/$^{238}$U ratios in the deeper strata samples. The average $^{226}$Ra/$^{238}$U ratio in the A and B horizons of the three surface soils is near 1.2 while the average value for the same ratio in HUs of HU-2 and below is 0.91 and the ratio in the Port Creek clay is 0.79. These observations imply preferential leaching of uranium (as compared to radium) from the surface soil horizons into to the deeper geologic horizons (e.g., out of the soil horizons into the HU-1 loess). The much lower $^{226}$Ra/$^{238}$U ratio in the old weathered Porter Creek clay may also imply either an accumulation of uranium as a consequence of leaching of uranium from the upper soil profile or preference leaching of radium relative to uranium from this geologic component. Other factors, such as particle size distribution, may also have a contributing influence.

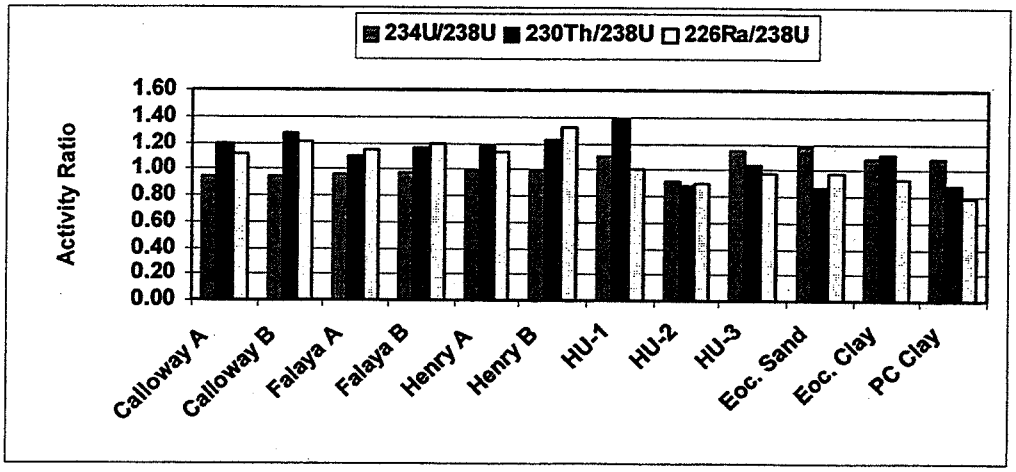


**Fig. 3.6. Activity ratios of the isotopes in the uranium decay series.**

## 3.4 FISSION PRODUCTS AND TRANSURANICS IN SOILS

Three of the most widely distributed fission products generated in fission reactions are $^{90}$Sr, $^{137}$Cs, and $^{99}$Tc. Strontium-90 and $^{137}$Cs are major contributors to global fallout due to atmospheric

testing of nuclear weapons in the 1950s to the early 1960s. Cesium-137 is commonly measured in soils throughout the world (Hutchison-Benson et al. 1985; Kiss et al. 1988; and Klechkovskii et al. 1972); $^{90}Sr$ to a lesser extent (Francis 1978). It is not unusual to observe activities of $^{137}Cs$ in surface soils ranging from 0.05 to as high as 3 pCi/g and its levels and distribution in soils have been used by numerous investigators to estimate erosion rates in soils (e.g., Ritchie and McHenry 1990 and Turnage et al. 1997).

Activities of $^{90}Sr$ tend to be lower than $^{137}Cs$ in surface soils because of two factors: (1) initial levels in global fallout were not as high and (2) $^{90}Sr$ mobility in most soils is significantly greater than $^{137}Cs$ making it more difficult to detect after the 30 or so years since the 1963 ban on above ground nuclear testing of weapons. In an analytical sense, $^{90}Sr$ is much more difficult to determine in soils than $^{137}Cs$ as the process requires wet-chemistry leaching of the soil matrix with subsequent separation and counting of the beta activity associated with the $^{90}Sr$. Cesium-137, on the other hand, can be measured directly using conventional gamma counting techniques. Technetium-99 yield in fission reactions is not as high as $^{137}Cs$ or $^{90}Sr$, but its long half-life ($2.1\times10^5$ y) makes it an environmental concern. It is also known to be associated with the reprocessing/enrichment of uranium fuels, and the presence of $^{99}Tc$ at PGDP is discussed in Phase II report (CH2M Hill 1992). Therefore, from this respect it would be one of the three fission products that might be considered to be a contaminant of concern in soils surrounding the PGDP. Because of this, measurements for $^{99}Tc$ were made in all soil profiles and deep geologic media. Technetium-99 is also very mobile in an oxidizing environment and has a high potential to move within geologic stratum.

The transuranics, $^{237}Np$, $^{238}Pu$, and $^{239}Pu$, are all alpha emitting radionuclides commonly associated with nuclear weapons production and production and processing/enrichment of uranium fuels. Because they are alpha emitting radionuclides, they represent a potential health risk, especially if inhaled or ingested into the human body. However, they are not customarily associated with uranium enrichment processes. Because their analyses are difficult and time consuming (and consequently costly), their activities were measured only in the A horizons of the three soils. A similar approach was taken for measurements of $^{90}Sr$ in soils because the analysis for $^{90}Sr$ is expensive and there has been little evidence from previous remedial investigations/feasibility studies that would indicate $^{90}Sr$ to be a contaminant of concern. Cesium-137 was measured in all samples because it could be measured by gamma spectroscopy methods in concert with the analyses of $^{40}K$, $^{226}Ra$ and other gamma emitting radionuclides adding little to the project's analytical costs.

Mean activities of $^{137}Cs$ were much higher in the A soil horizons than the B horizons (Fig. 3.7). In fact, the mean activities of $^{137}Cs$ in the B horizon of the Calloway soil and the deep geologic media were estimated to be zero. The levels of $^{137}Cs$ in the A soil horizons ranged from 0.104 to 0.438 pCi/g (mean of 0.248 pCi/g). Earlier monitoring studies at PGDP (from 1988 to 1993) revealed similar background levels of $^{137}Cs$ (mean activity of 0.657 pCi/g over range of 0.11 to 4.0 pCi/g, see Table A.2 in DOE 1996b). A greater range in $^{137}Cs$ activities was also observed in the Oak Ridge background soils study (0.021 to 2.09 pCi/g). However, the Oak Ridge study involved 24 individual soils (with no compositing that may account for the greater range in activities). Estimated mean activities for $^{90}Sr$ (the other fission product commonly associated with worldwide fallout) in the A horizons of the three soils sampled were also considered to be zero (Table 3.1).

Measurements for $^{99}Tc$ were highly variable across surface soils as well as the deep geologic media. For example, the highest mean value was 0.825 pCi/g in the B horizon of the Henry soil. The mean value for the A horizon of the same soil was 0.122 pCi/g. Mean values in the A and B horizons, across all three soils, were 0.151 and 0.395 pCi/g, respectively. The high mean value observed in the B horizon appears to be due to the 3.0 pCi/g measured in one of the composited

samples of the Henry soil. This value is clearly a statistical outlier; however, there was no legitimate analytical reason for deleting the analyses from the data set. Estimates for the mean activity in the HU-1, HU-2, and Eocene sands were 0.000 (Table 3.1) while the single measurement in the Eocene clay contained 0.248 pCi/g (Fig. 3.8). Values for $^{99}$Tc in this study (even with the inclusion of the single apparent outlier that contained nearly 3 pCi/g) appear to be much lower than the values reported in the earlier Phases I and II site investigations (Appendix A, DOE 1996b) or that reported in the Oak Ridge background study (DOE 1993). For example, median values in the Oak Ridge study ranged from 1.11 to 3.99 pCi/g; however, only nine values were reported as detectable in the Oak Ridge study. For this study, all 56 soil samples were characterized as detects.

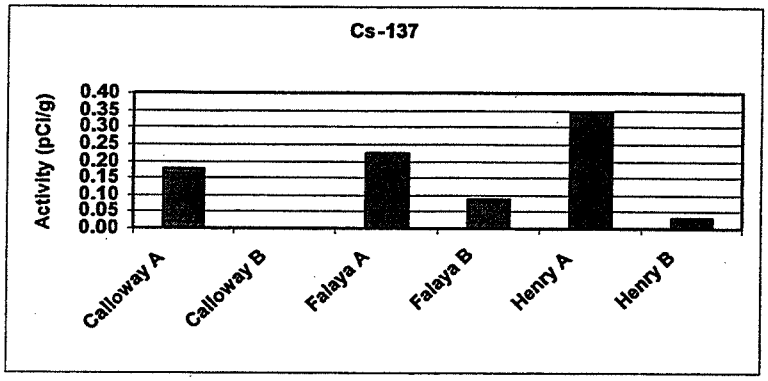


**Fig. 3.7. Mean activities of $^{137}$Cs in surface soils.**

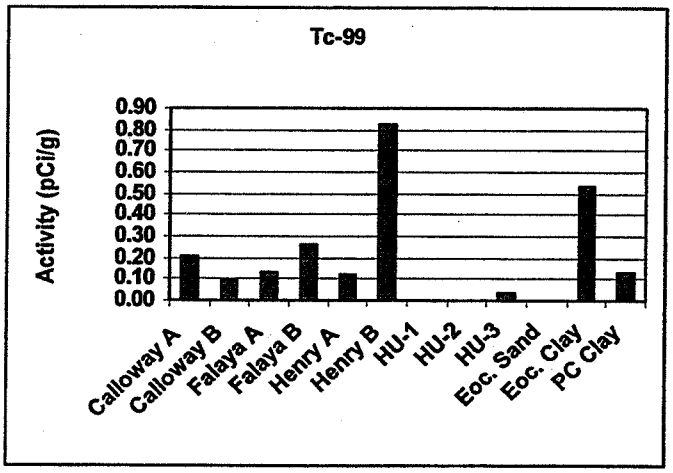


**Fig. 3.8. Mean activities of $^{99}$Tc.**

Very low levels of transuranics were measured in the A horizons of the surface soils. In addition, little difference was noticed in the activity of either of the three isotopes with respect to soil series (see Table 3.5 and Fig. 3.9).

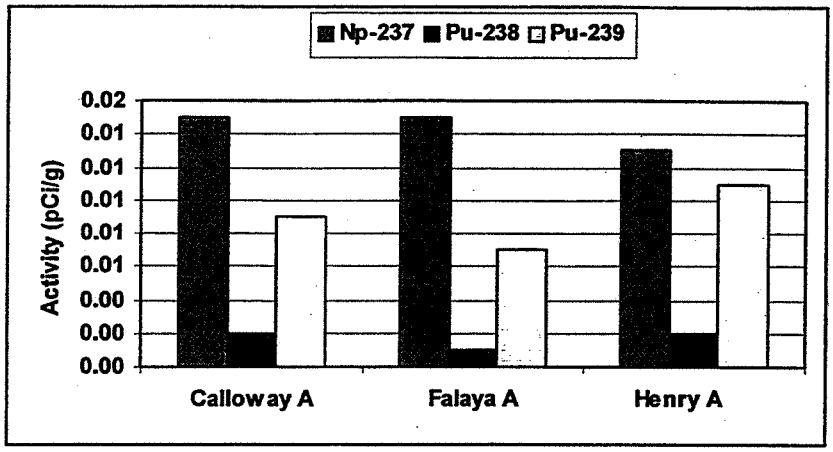


**Fig. 3.9. Mean activities of transuranics in the surface soils.**

## 3.5 DISTRIBUTION AND ACTIVITIES OF NATURAL $^{40}$K

The radionuclide exhibiting the highest activity in all soils and deep geologic media was $^{40}$K. Mean activities in the surface soils ranged from 13.0 to 14.1 pCi/g. The loess (HU-1) horizon contained approximately the same level of activity as the surface soils; however, the HU-2, HU-3, and the Eocene sands contained much lower activities (Fig. 3.10). The single sample of Eocene clay and Porter Creek clay samples contained 2 to 9 times more $^{40}$K than the samples from the HU-2, HU-3, and Eocene sands, indicating a relationship between clay content and $^{40}$K activity; however, statistical analyses showed no significant correlations between the two (see Appendix G).

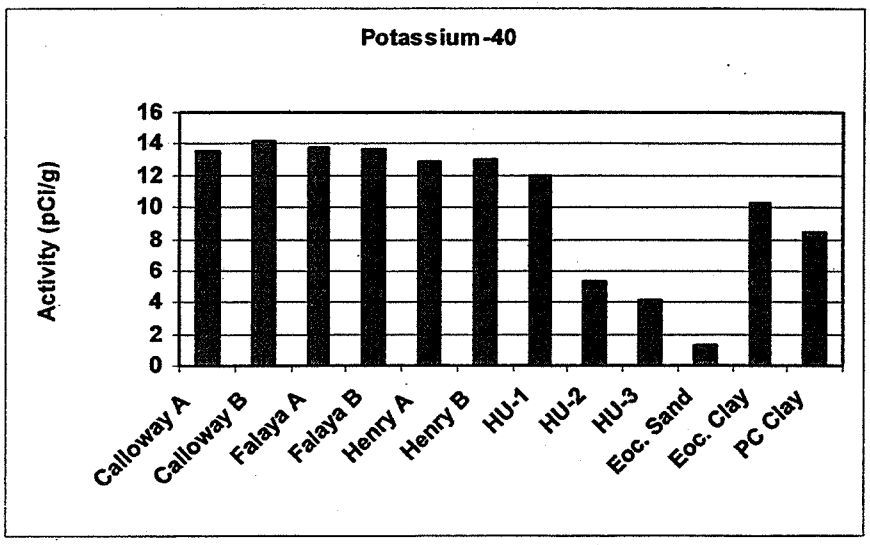


**Fig. 3.10. Mean activity of $^{40}$K.**

## 3.6 DISTRIBUTION AND CONCENTRATION OF METALS

The detection level for metals (Be, Cd, Sb, and Tl) using ICP-MS methods for analyses was approximately 0.2 mg/kg. This level of detection provides adequate information to allow calculation of risks associated with these metals (see Section 4.0 "Background Risk Evaluation"). All 56 samples were below the detection levels for antimony and cadmium (see Table 3.2). Beryllium in the Eocene sands was below detection levels; however, detectable levels were observed in the other hydrologic units as well as in all samples of surface soil. The Porter Creek clay contained beryllium levels more than twice that measured in any other soil horizon or hydrologic unit (see Fig. 3.11). Thallium was detected in only 20 of the 56 samples and mean concentrations in those samples were very close to 0.2 mg/kg (Table 3.2).

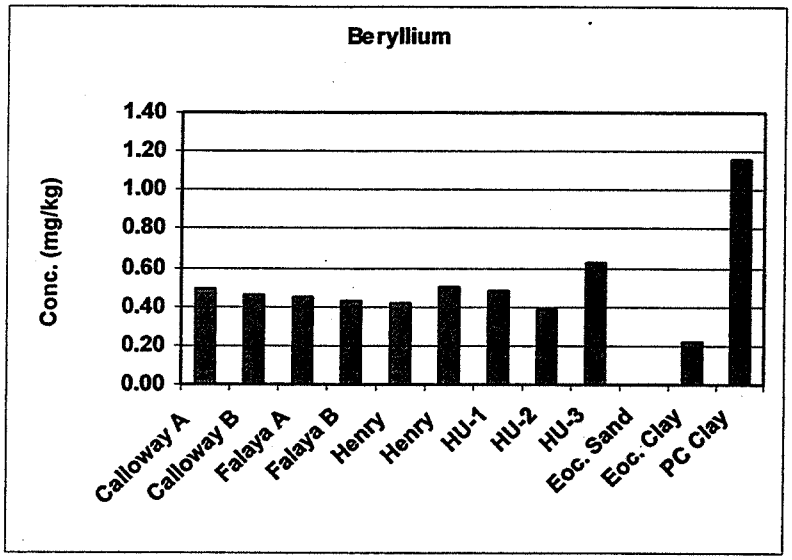


**Fig. 3.11. Concentration of beryllium in surface soils and hydrologic units.**

Measured values for metals in this work are much lower than those measured in surface soils for the earlier Phases I and II site investigations. The Phase II investigation (CH2M Hill 1992) detected antimony (concentration of 0.39 mg/kg) in only one of the five samples. Levels for beryllium (estimated using an analytical qualifier) ranged from 7.6 to 17.8 mg/kg (total of five samples analyzed). For cadmium, estimates ranged from 0.86 to 2.6 (total of five samples analyzed). Thallium was measured in two of the five samples at 0.3 and 0.44 mg/mg; however, the analyte was also observed in the associated blanks). This present study involved analyses of 56 samples using analytical methods capable of measuring concentrations significantly lower than that detected (or estimated) in earlier studies.

## 3.7 STATISTICAL ANALYSES AND INTERPRETATIONS

### 3.7.1 Outlier Analyses

The objective in these analyses was to detect possible outliers within specific data sets. For example, statistical analysis began with plotting results for each analyte as well as various isotopic ratios (e.g., $^{228}Th/^{230}Th$, $^{230}Th/^{234}U$). Figure 3.12 is an example of such a plot. Outliers identified with these plots were considered as possible suspects in the data validation. The plots were also used to

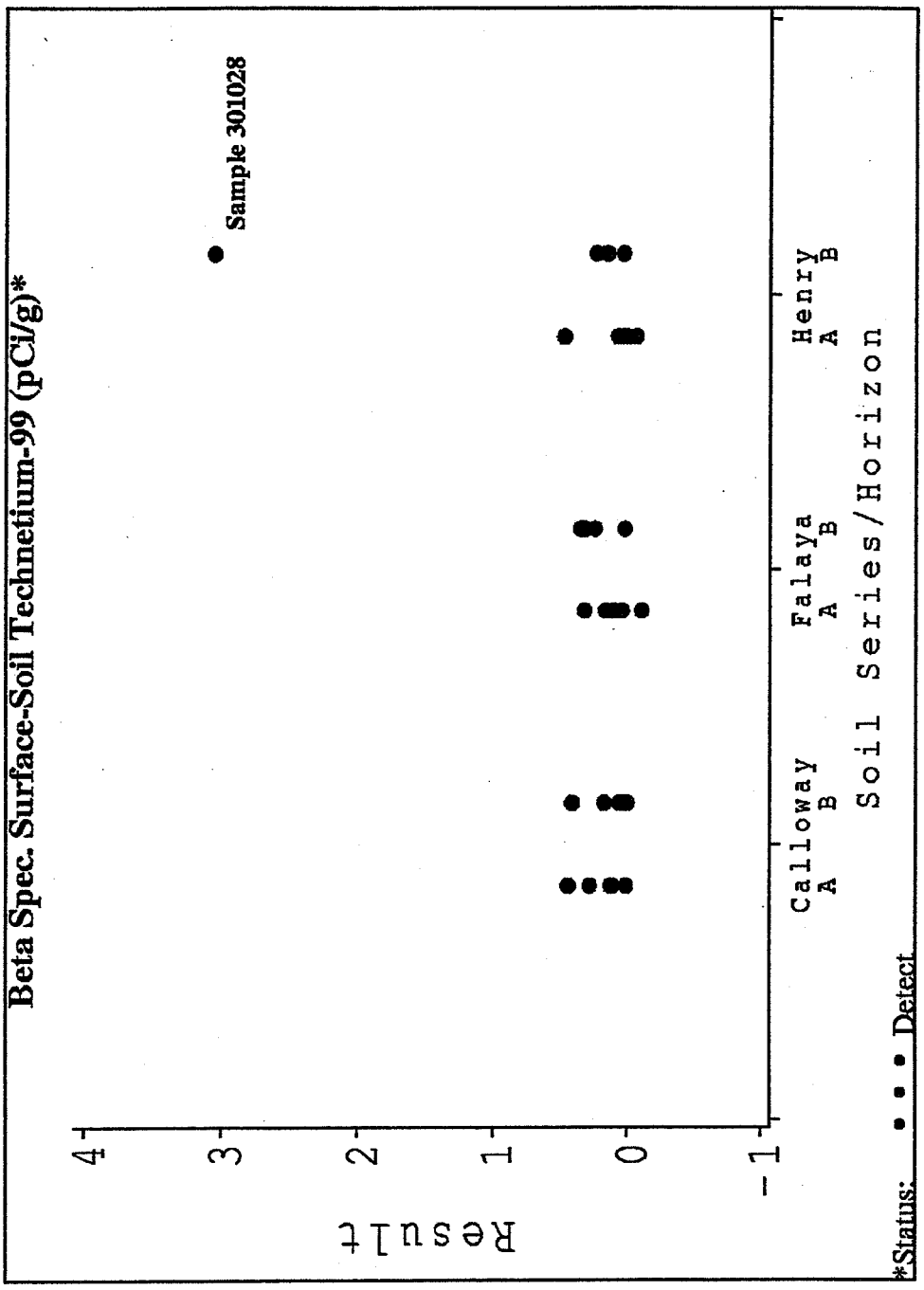


Fig. 3.12. Illustration of process to identify potential outliers.

help decide about a parametric (e.g., normal, lognormal, etc.) distribution for modeling in the statistical analysis. The normal approach was a priori preferred, because it involves no transformations (such as logs) of the data, and is therefore most tractable for the analysis of composites. (Consider, for example, the log of a composite, which is not the same as an average or "composite" of logs. It has statistical behavior that is much harder to characterize.) Difficulties with the lognormal approach are discussed in the EPA's "Soil Screening Guidance" (EPA 1996, Section 4) and by Schmoyer et al. (1996). In addition to difficulties with composites, these difficulties include anomalous behavior of lognormal-based estimates. The difficulties further motivate the normal distribution, at least over the lognormal.

### 3.7.2 Goodness-of-Fit Tests

The outlier plots suggested that the normal distribution would provide a reasonable model for the analyte statistical distributions. Formal goodness-of-fit tests for normality were then performed for each analyte, at the 0.05 level of significance, separately for the deep and surface data. The tests rejected for 2 of the 19 surface-soil target analytes ($^{226}$Ra, p=0.04; and $^{99}$Tc, p=0.0001) and for 1 of the 15 deep-soil analytes (alpha $^{238}$U, p=0.01). The level of significance for the remaining analytes all exceeded 0.05 or could not be computed because of nondetects. A few rejections (about 5%) can be attributed to making multiple tests at the 0.05 significance level. (We expect 5% rejection even when the normal distribution holds exactly). The rejection for surface-soil $^{99}$Tc (see Fig. 3.12) can be attributed to an obvious outlier. (Note, this outlier was not discarded from the data analyses.) Other apparent departures from normality did not seem severe, so we elected to model the data as normal.

### 3.7.3 Main Summary Statistics

For statistical comparisons of analyte concentrations and activities among soil series, horizons and other classifications, the data were analyzed using normal-model approaches, with no log (or any other) transformation. For the surface data, analysis of variance (ANOVA) was used to simultaneously estimate laboratory error variance, overall (spatial and laboratory) error variance, means for individual series-horizon groups, and to compare the groups. With an estimate of overall and laboratory variance, the spatial error variance could also be estimated by computing the difference, laboratory from overall.

The mechanism for estimating the laboratory error variance was straightforward: compute the sum of squared sample-duplicate differences and divide by the number of sample-duplicate pairs. The mechanism for estimating the combined spatial and laboratory error, which is much more complicated, is discussed in Searle (1971, Chapter 9). The idea is to compute the statistical expectation of an ANOVA mean squared error, and then to adjust it to obtain an unbiased estimate of the spatial error variance. Further, the ANOVA mean square for overall spatial and laboratory error is the appropriate denominator for tests (F-tests) about differences between horizons, series, etc. Significance levels for those tests are in Table 3.8. The variance component estimates are used to compute percentile estimates and tolerance bounds. The percentile estimates and tolerance bounds, which are in Tables 3.1 through 3.6, are for ordinary noncomposite samples. As they depend on the spreads (variances) of the analyte statistical distributions, it is necessary to infer estimates of those variances from the variances of the composites.

Variance estimates for noncomposites can be computed using the formula for the variance of a composite of k, $\sigma_L^2 + \sigma_S^2/k$, where $\sigma_L^2$ and $\sigma_S^2$ are the lab and spatial variances of individual (noncomposite) samples. Therefore, given an estimate of $\sigma_L^2$ (from lab duplicates) and the overall variance of the composites of three $\sigma_L^2 + \sigma_S^2/3$, we can solve for an estimate of $\sigma_S^2$ and thus an

estimate $\hat{\sigma}^2$ of $\sigma_L^2 + \sigma_S^2/k$ for k=1 (noncomposites) or for any k. These variance estimates are unlike usual (mean squared error) variance estimates in that even if the data are exactly normally distributed, they do not have exact chi-square distributions. However, they are approximately chi-square with degrees of freedom which we determined using the method of Satterthwaite (1946).

These variance estimates and degrees of freedom were combined with the mean estimates to compute normal percentile estimates and tolerance bounds. Both the percentile and tolerance bound estimates are of the form

$$\hat{\mu} \pm \tau\hat{\sigma}$$

where $\hat{\mu}$ is the mean estimate, and $\tau$ is a constant, 1.64 (the 95 percentile) for the percentile estimate, or a value (determined from the non-central t-distribution, see Owen (1966, p 117)) for the upper or lower tolerance bounds.

For estimating means (as opposed to percentiles), ordinary averages and their standard errors can be used without adjusting for the differences in the variance of composites vs noncomposites. (The composites directly estimate the means, and as physical averages, are less variable.)

For deep soils, because of the unbalanced experimental sampling design, ANOVA is not a convenient instrument for statistical analysis. For example, HU-1 samples were taken from boreholes 196-01&02 ("&" denoting composite), 196-03&04, 194-03&04, and 194-05&06. HU-1L samples were taken from boreholes 194-01&02, 194-03&04 (plus duplicate), and 194-05&06. Thus, for comparing HU-1 with HU-1L, only the 194-03&04 and 194-05&06 samples should be used. Therefore special comparisons and their standard errors were calculated (by specifically coding for them) to test for differences between the various hydrologic units and the Porter Creek and Eocene Sands formations. Significance levels for the deep-soil comparisons are presented in Table 3.9. Means, standard errors, and confidence bounds for each group of interest (e.g., Eocene sands) are computed by accumulating results for that group. Because of the unbalanced design, however, these means may not be directly comparable.

For both deep and surface soils, thallium had a mixture of detects and nondetects, and so the estimation procedure used for thallium differed from that for the other analytes. The procedure for thallium (see Lawless 1982) is based on maximum likelihood estimation under the normal model.The SAS Lifereg procedure (SAS 1990), where it is implemented, was used to compute the estimates. In addition, beryllium had no detects in the Eocene sands formation, and there were no detects anywhere for antimony or cadmium.

## 3.8 COMPARISONS BETWEEN METHODS OF ANALYSES

Three different analytical methods were used to measure $^{232}Th$, $^{235}U$, and $^{238}U$ (Table 2.3). These included alpha spectroscopy, ICP-MS, and NAA. Two of the methods (alpha spectroscopy and ICP-MS) require separation of the analyte from the soil matrix. For the ICP-MS analyses, this is accomplished by leaching the soil samples with a combination of nitric and hydrochloric acids as outlined in EPA-6020 method. The alpha spectroscopy method uses a more aggressive nitric acid/hydrofluoric acid dissolution process as outlined in EPA-908m. NAA does not require separation of the analyte from the soil matrix as the method measures the intensity of selected gamma radiation spectra integrated over time after bombardment of the sample with neutrons.

**Table 3.8. Statistical comparison tests for analyte actitivies within surface soil series and soil horizons[a]**

| Method | Analyte | Series | Horizon | Series x Horizon Interaction | Notes[b] |
|---|---|---|---|---|---|
| ICP-MS | Beryllium | | | | |
| Gamma | Cesium-137 | .004[b] | .0001 | .01 | C<F,H; B<A |
| Alpha | Neptunium-237 | | | | |
| Alpha | Plutonium-238 | | | | |
| Alpha | Plutonium-239 | | | | |
| Gamma | Potassium-40 | .04 | | | H<F,C |
| Gamma | Radium-226 | .007 | | | F<H,C |
| Beta | Strontium-90 | | | | Horizon A data only |
| Beta | Technetium-99 | | | | |
| ICP-MS | Thallium[c] | | | | A<B |
| Alpha | Thorium-228 | | | | Series p=.06 |
| Alpha | Thorium-230 | .0001 | | | |
| Alpha | Thorium-232 | .003 | | | F<H,C |
| Alpha | Uranium-233/34 | .007 | .02 | | F<H,C; B<A |
| Alpha | Uranium-235 | | | | |
| Alpha | Uranium-238 | .003 | .04 | | F<H,C; B<A |
| Alpha | Uranium-Total | .003 | .04 | | F<H,C; B<A |

Notes:

[a]Significance levels for tests of difference. Only levels 0.05 or less are shown.

[b]C=Calloway; F=Falaya; H=Henry. A,B—horizons.

[b]Probability that the analyte levels in the soil series or soil horizons are the same or statistically equivalent.

[c]Formal tests not computed for thallium because of large number of nondetects.

**Table 3.9. Significance levels for comparisons of hydrologic units and formations**

| Method | Analyte | Units | HU1 x HU1L | HU1L x HU2 | HU1L x HU3 | HU2 x HU3 | HU1 x HU2 | HU1 x HU3 | HU1 x ES | HU1 x PC | HU1L x PC | HU3 x PC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ICP-MS | Be | mg/kg | .831 | .231 | .000 | .000 | .165 | .850 | .000 | .000 | .000 | .000 |
| Gamma | Cs-137 | pCi/g | .810 | .799 | .995 | .748 | .810 | .552 | .764 | .299 | .959 | .750 |
| Gamma | K-40 | pCi/g | .001 | .000 | .000 | .090 | .000 | .000 | .000 | .000 | .000 | .000 |
| Gamma | Ra-226 | pCi/g | .518 | .131 | .289 | .001 | .350 | .615 | .004 | .081 | .185 | .211 |
| Beta | Tc-99 | pCi/g | .778 | .151 | .455 | .922 | .694 | .855 | .449 | .190 | .066 | .265 |
| Alpha | Th-228 | pCi/g | .034 | .042 | .086 | .000 | .851 | .078 | .000 | .006 | .097 | .247 |
| Alpha | Th-230 | pCi/g | .000 | .000 | .000 | .000 | .037 | .037 | .000 | .648 | .000 | .007 |
| Alpha | Th-232 | pCi/g | .033 | .064 | .906 | .001 | .814 | .110 | .000 | .017 | .695 | .441 |
| Alpha | U-233/234 | pCi/g | .825 | .405 | .025 | .000 | .486 | .188 | .000 | .001 | .001 | .000 |
| Alpha | U-235 | pCi/g | .059 | .809 | .174 | .744 | .942 | .316 | .169 | .045 | .318 | .007 |
| Alpha | U-238 | pCi/g | .317 | .067 | .009 | .000 | .012 | .245 | .000 | .000 | .000 | .000 |
| Alpha | U-Tot | mg/kg | .317 | .067 | .009 | .000 | .012 | .245 | .000 | .000 | .000 | .000 |

Therefore, it eliminates any error associated with the dissolution or leaching process of the sample. In addition, it does not require any further chemical separation of a specific element in the acid extractant such as that required for uranium and thorium in alpha spectroscopy.

For many analytes, NAA is considered the most accurate; however, its availability is generally limited due to the need of a nuclear reactor and the required counting facilities. Alpha spectroscopy is generally preferred as the conventional counting technique for alpha emitting nuclides in that it is highly specific (resolution of the alpha spectra is relatively easy) and sensitive because the quantity of sample is not as limiting as it is for ICP-MS. For example, in this study the levels of $^{235}U$ in soil were below ICP-MS detection limits (all 56 samples were below detection, < 0.02 mg/kg).

This study revealed very similar results if alpha spectroscopy and NAA were used for analysis of either $^{238}U$ and $^{232}Th$. Analyses by ICP-MS generally under estimated levels of $^{238}U$ and $^{232}Th$ (see Figs. 3.13 and 3.14). For $^{235}U$, alpha spectroscopy generally overestimated activities as compared to NAA (see Fig. 3.15).

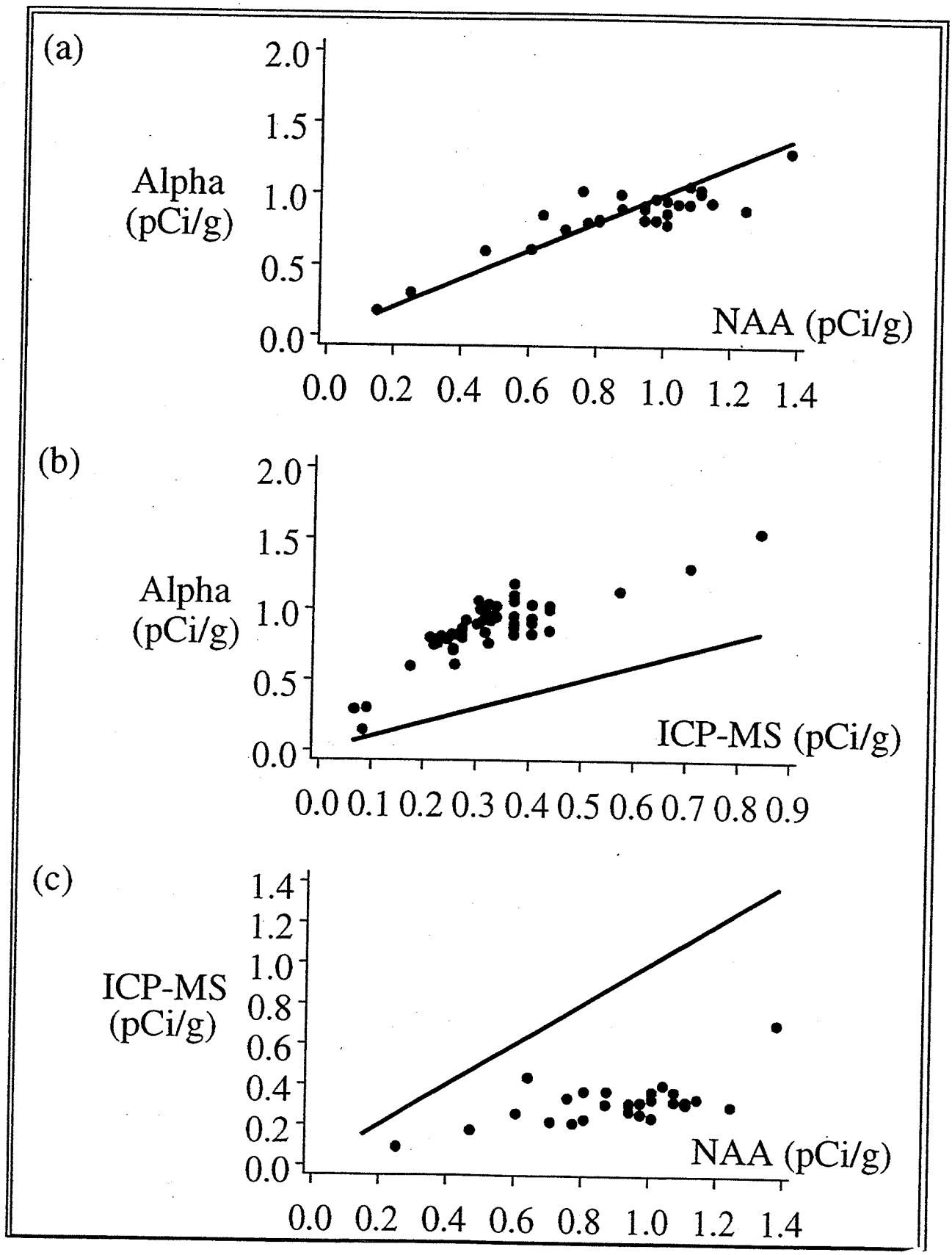


**Fig. 3.13. Comparison of analytical methods in the measurements of $^{238}U$; reference line denotes identical levels between methods. (a) alpha vs NAA, (b) ICP vs NAA, (c) alpha vs ICP-MS.**

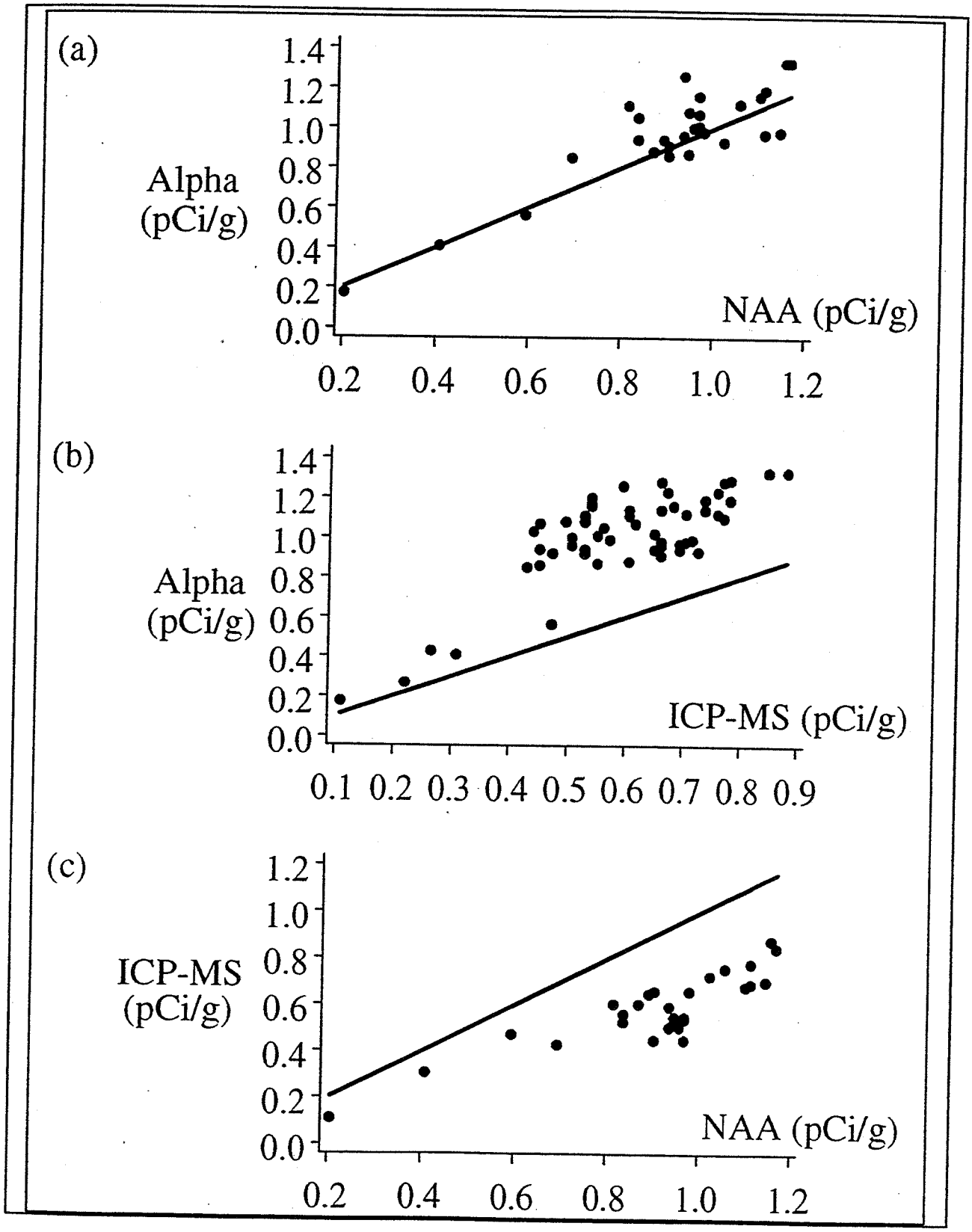


**Fig. 3.14. Comparison of analytical methods in the measurement of $^{232}Th$; reference line denotes identical levels between methods. (a) alpha vs NAA, (b) ICP vs NAA, (c) alpha vs ICP-MS.**

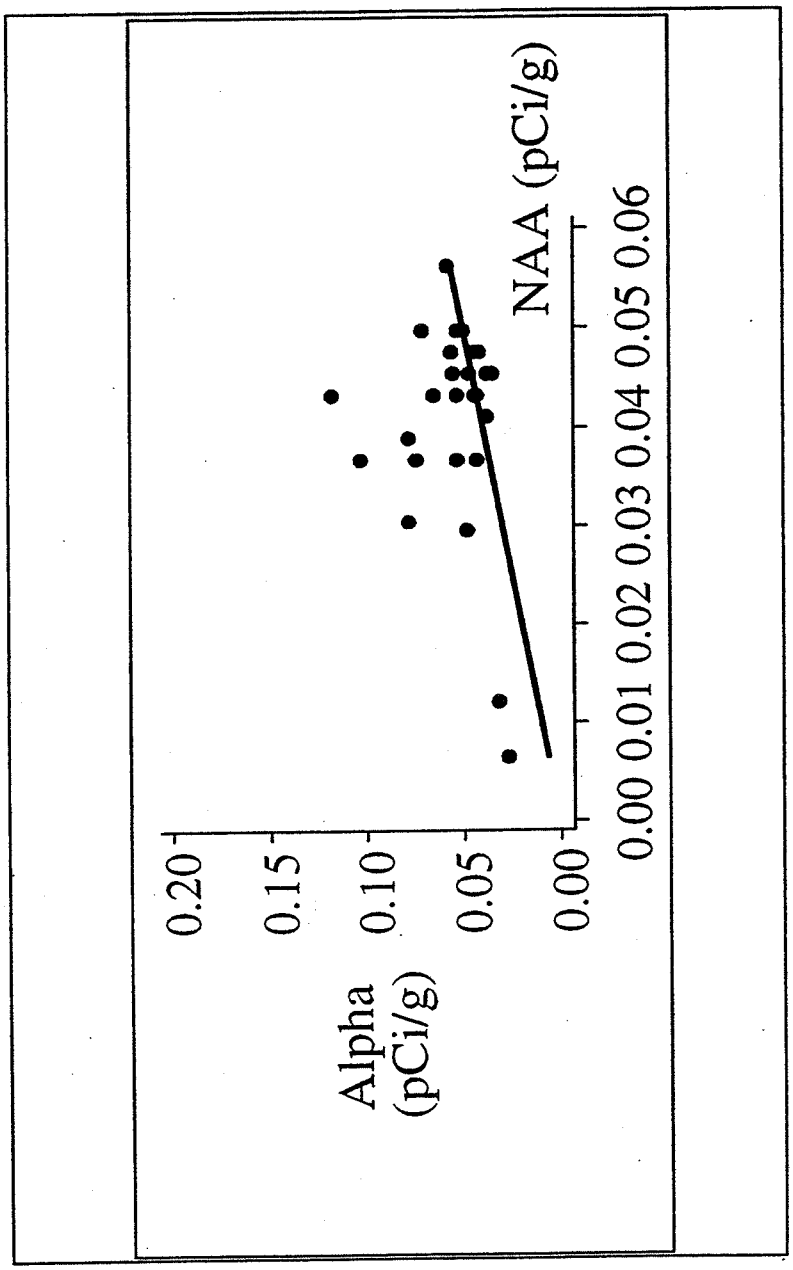


**Fig. 3.15. Comparison of alpha spectroscopy and NAA to measure $^{235}U$ in surface soils and deep geologic media.**

# 4. BACKGROUND RISK EVALUATION

## 4.1 INTRODUCTION

This chapter presents the risk evaluation of the background concentrations developed in Chapter 3. In this risk evaluation, the background concentrations of each analyte are compared to risk-based or hazard-based human health and ecological screening criteria. In addition, future use of these background concentrations in risk evaluations and assessments at PGDP and the uncertainties their use presents to the selection of clean-up goals are discussed.

## 4.2 COMPARISON OF BACKGROUND CONCENTRATIONS TO SCREENING CRITERIA

In this part of the risk evaluation, background concentrations determined by the statistical analysis in Chapter 3 and in *Background Concentrations and Human Health Risk-based Screening Criteria for Metals in Soil at the Paducah Gaseous Diffusion Plant, Paducah Kentucky* (DOE 1996a) are compared to human health and ecological risk-based screening criteria. (Note, background values taken from DOE 1996a are also presented here so that a single list of soil background values is made available. It is believed by the author that a single list for all soil analytes for which background concentrations exist will prevent confusion in the future due to the existence of multiple lists.) The human health risk-based screening criteria are drawn from two sources: Appendix 1 of *Methods for Conducting Human Health Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant* (DOE 1996c) and Appendix A of *Risk Assessment Guidance* (KyDEP 1995). The ecological risk-based screening criteria are drawn from *Preliminary Remediation Goals for Ecological Endpoints* (Energy Systems 1996)

### 4.2.1 Comparison Against Human Health Screening Criteria

In this subsection, background concentrations in surface (0 to 1 ft below ground surface) and subsurface soil (greater than 1 ft below ground surface) are compared against human health risk-based and hazard-based screening criteria (i.e., preliminary remediation goals, PRGs) for both industrial and residential use. As noted previously, the risk-based and hazard-based PRGs are taken from DOE 1996c, and generic human health screening values are taken from KyDEP 1995. The methods used to derive these screening criteria are presented in Appendix 2 of DOE 1996c and Subsect. 2.1.1 of KyDEP 1995, respectively.

#### 4.2.1.1 Inorganic chemicals

**Interpretation of figures.** In the following discussions, in figures comparing the background concentrations of inorganic chemicals and excess lifetime cancer risk-based PRGs, the background concentration of an inorganic chemical is said to significantly exceed its excess lifetime cancer risk-based PRG when the value indicated by the solid square on the appropriate figure is greater than 3. When the value indicated by the solid square is between 0 and 3, the background concentration of the inorganic chemical is said to exceed, but not significantly, its respective excess lifetime cancer risk-based PRG. Finally, when the value indicated by the solid square is less than 0, the inorganic chemical's background concentration is said to not exceed its excess lifetime cancer risk-based PRG. (The value indicated by the solid square on figures depicting the comparison between background concentrations and excess lifetime cancer risk-based PRGs is equal to the

logarithm of the background concentration of the inorganic chemical divided by the chemical's residential or industrial excess lifetime cancer risk-based PRG. A full discussion of the derivation and interpretation of these figures is in Appendix E of *Data Summary and Interpretation Report for Interim Remedial Design at Solid Waste Management Unit 2 of Waste Area Grouping 22 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* [DOE 1996d].) Note, when the value indicated by the solid square is greater than 3, the background concentration is said to significantly exceed its excess lifetime cancer risk-based PRG because the risk calculated for a residential or industrial receptor directly contacting soil containing the inorganic chemical alone at the background concentration would be greater than $1 \times 10^{-4}$, if the risk calculation used the default exposure factors used to calculate the excess lifetime cancer risk-based PRG.

In addition, in the following discussions, in figures comparing the background concentrations of inorganic chemicals and systemic hazard-based PRGs, the background concentration of an inorganic chemical is said to significantly exceed its systemic hazard-based PRG when the value indicated by the solid square on the appropriate figure is greater than 1. When the value indicated by the solid square is between 0 and 1, the background concentration of the inorganic chemical is said to exceed, but not significantly, its respective systemic hazard-based PRG. Finally, when the value indicated by the solid square is less than 0, then the inorganic chemical's background concentration is said to be less than its respective systemic hazard-based PRG. (In this case, the value indicated by the solid square is equal to the logarithm of the background concentration of the inorganic chemical divided by the chemical's residential or industrial systemic hazard-based PRG. A full discussion of the derivation and interpretation of these figures is also in Appendix E of DOE 1996d.) Note, when the value indicated by the solid square is greater than 1, the background concentration is said to significantly exceed its systemic hazard-based PRG because the potential hazard index calculated for a residential or industrial receptor contacting soil containing the inorganic chemical alone at the background concentration would be greater than 1, if the calculation used the default exposure factors used to calculate the systemic hazard-based PRG. When a hazard calculation yields a hazard index of greater than 1, systemic effects may be seen in receptors.

**Surface soil.** Table 4.1 and Figs. 4.1 (industrial use, excess lifetime cancer risk), 4.2 (residential use, excess lifetime cancer risk), 4.3 (industrial use, systemic hazard), and 4.4 (residential use, systemic hazard) present the comparison of the selected background concentrations of inorganic chemicals in surface soil against human health risk-based screening criteria. In the table and figures, the background concentrations for Be, Tl, and U are the 95% upper tolerance bound on the 95$^{th}$ percentile concentration in A horizon soil calculated in Chapter 3, and the background concentrations for antimony and cadmium are the maximum detection limits in A horizon soil presented in Chapter 3. For all other inorganic chemicals, the background concentrations were taken from Table E.1 of DOE 1996a.

The background concentrations for Be, Tl, and U were set at their 95% upper tolerance bound on the 95$^{th}$ percentile concentration to remain consistent with the background threshold values selected in DOE 1996a. The reason for selecting the 95% upper tolerance bound on the 95$^{th}$ percentile concentration is discussed in Subsect. 2.1.2.2 of DOE 1996a. The background concentrations for antimony and cadmium were set at their maximum detection limits because these inorganic chemicals were not detected in A horizon soils collected during the background soils project (see Chapter 3).

As shown in Figs. 4.1 and 4.2, the background concentration for beryllium in surface soil significantly exceeds its industrial and residential excess lifetime cancer risk-based PRG. The background concentration for arsenic in surface soil significantly exceeds its residential excess

**Table 4.1. Comparison of background concentrations of inorganic chemicals[a] in surface soil (0 to 1 foot below ground surface) to human health screening criteria**

| Inorganic Chemical | Background Value[b] | Industrial Preliminary Remediation Goal[c] | | Residential Preliminary Remediation Goal[d] | | KyDEP Screening Value[e] |
|---|---|---|---|---|---|---|
| | | ELCR | HI | ELCR | HI | |
| Aluminum | 13,000 | --- | 4,700 | --- | 730 | 7,700 |
| Antimony[f] | 0.21 | --- | 0.38 | --- | 0.064 | 3.1 |
| Arsenic[g] | 12 | 0.033 | 5.3 | 0.0092 | 0.69 | 0.032 |
| Barium[h] | 200 | --- | 230 | --- | 37 | 530 |
| Beryllium[i] | 0.67 | 0.00031 | 2.4 | 0.00010 | 0.40 | 0.014 |
| Cadmium[j] | 0.21 | 1,000 | 2.4 | 290 | 0.39 | 3.8 |
| Calcium | 200,000 | --- | --- | --- | --- | --- |
| Chromium (III)[k] | 16 | --- | 200 | --- | 33 | --- |
| Chromium (VI) | [l] | 150 | 4.7 | 42 | 0.79 | 3.0 |
| Cobalt | 14 | --- | 1,900 | --- | 210 | --- |
| Copper[m] | 19 | --- | 530 | --- | 74 | 280 |
| Cyanide ($CN^-$) | [n] | --- | 160 | --- | 23 | 130 |
| Iron | 28,000 | --- | 2,100 | --- | 310 | --- |
| Lead[o] | 36 | --- | 0.00069 | --- | 0.00011 | 20 |
| Magnesium | 7,700 | --- | --- | --- | --- | --- |
| Manganese[p] | 1,500 | --- | 88 | --- | 15 | 38 |
| Mercury[q] | 0.20 | --- | 0.98 | --- | 0.16 | 2.3 |
| Nickel[r] | 21 | --- | 240 | --- | 34 | 150 |
| Potassium | 1,300 | --- | --- | --- | --- | --- |
| Selenium | 0.80 | --- | 95 | --- | 12 | 38 |
| Silver[s] | 2.3 | --- | 41 | --- | 6.1 | 38 |
| Sodium | 320 | --- | --- | --- | --- | --- |
| Sulfide | [l] | --- | --- | --- | --- | --- |
| Thallium | 0.21 | --- | --- | --- | --- | --- |
| Tin[t] | [l] | --- | 2,800 | --- | 440 | 4,600 |
| Uranium[u] | 4.9 | --- | 101 | --- | 11 | 11 |
| Vanadium[v] | 38 | --- | 3.3 | --- | 0.56 | 54 |
| Zinc[w] | 65 | --- | 2,700 | --- | 400 | 2,300 |

**Table 4.1. (continued)**

Notes: Cells with dashes (---) indicate data are not available or not applicable.
All values in mg/kg.

[a] Includes inorganic chemicals found on Target Analyte List as defined by EPA in 1988 CLP Statement of Work and RCRA Appendix IX list of constituents.

[b] Value for use in screening to determine if inorganic chemical was detected at naturally occurring concentration in surface soil. Details on the derivation of the background concentrations for antimony, beryllium, cadmium, thallium, and uranium are in Sect. 2 of this report. Details in the derivation of the background concentration of all other inorganic chemicals are in DOE 1996a.

[c] Industrial use preliminary remediation goal calculated using as target values an excess lifetime cancer risk (ELCR) of $1 \times 10^{-7}$ or a hazard index (HI) of 0.1. Preliminary remediation goals for all analytes, except that for lead, taken from Table 1 in Appendix 1 of DOE 1996b. The derivation of these values is in Appendix 2 of DOE 1996b. The value for lead was calculated using methods in Appendix 2 of DOE 1996b and toxicity values provided in comments on the WAG 17 report (KyDEP 1997).

[d] Residential use preliminary remediation goal calculated using as target values an excess lifetime cancer risk (ELCR) of $1 \times 10^{-7}$ or a hazard index (HI) of 0.1. Preliminary remediation goals for all analytes, except that for lead, taken from Table 2 in Appendix 1 of DOE 1996b. The derivation of these values is in Appendix 2 of DOE 1996b. The value for lead was calculated using methods in Appendix 2 of DOE 1996b and toxicity values provided in comments on the WAG 17 report (KyDEP 1997). Note, values for systemic hazard (i.e., HI values) are for a child aged 1 to 7 years.

[e] All values, except that for lead, are one-tenth of the soil screening value presented in KyDEP 1995. Use of one-tenth of the screening value for all but lead is in accordance with guidance on use of screening values in KyDEP 1995. Value for lead is the screening value and not one-tenth of the screening value. Use of this value is in accordance with guidance on use of screening values in KyDEP 1995.

[f] Industrial and residential PRGs are those for "Antimony (Metallic)" (Chemical Abstract Service Registry Number [CAS#] 7440-36-0) in DOE 1996b. KyDEP screening value is that for "Antimony and compounds."

[g] Industrial and residential PRGs are those for "Arsenic (Inorganic)" (CAS# 7440-38-2) in DOE 1996b. KyDEP screening value is that for "Arsenic and compounds."

[h] KyDEP screening value is that for "Barium and compounds."

[i] KyDEP screening value is that for "Beryllium and compounds."

[j] Industrial and residential PRGs are those for "Cadmium (water)" (CAS# 7440-43-9) in DOE 1996b. KyDEP screening value is that for "Cadmium and compounds."

[k] Industrial and residential PRGs are those for "Chromium (III) (Insoluble Salts)" (CAS # 16065-83-1) in DOE 1996b.

[l] Data are not adequate to calculate a background concentration in soil for this analyte.

[m] KyDEP screening value is that for "Copper and compounds."

[n] Cyanide is not expected to be naturally occurring at PGDP; therefore a background value was not derived.

[o] See footnotes c, d, and e for additional information concerning values for lead.

[p] Industrial and residential PRGs are those for Manganese (Water)" (CAS# 7439-96-5) in DOE 1996b. KyDEP screening value is that for "Manganese and compounds."

[q] Industrial and residential PRGs are those for "Mercury (Inorganic Salt)" (CAS# 7439-97-6) in DOE 1996b.

[r] Industrial and residential PRGs and those for "Nickel (Soluble Salts)" (CAS# 7440-02-0) in DOE 1996b.

[s] KyDEP screening value is that for "Silver and compounds."

[t] KyDEP screening value is that for "Tin and compounds."

[u] Industrial and residential PRGs and those for "Uranium (Soluble Salts)" (CAS# 7440-61-1) in DOE 1996b.

[v] Industrial and residential PRGs and those for "Vanadium (Metallic)" (CAS# 7440-62-2) in DOE 1996b.

[w] Industrial and residential PRGs and those for "Zinc (Metallic)" (CAS# 7440-66-6) in DOE 1996b.

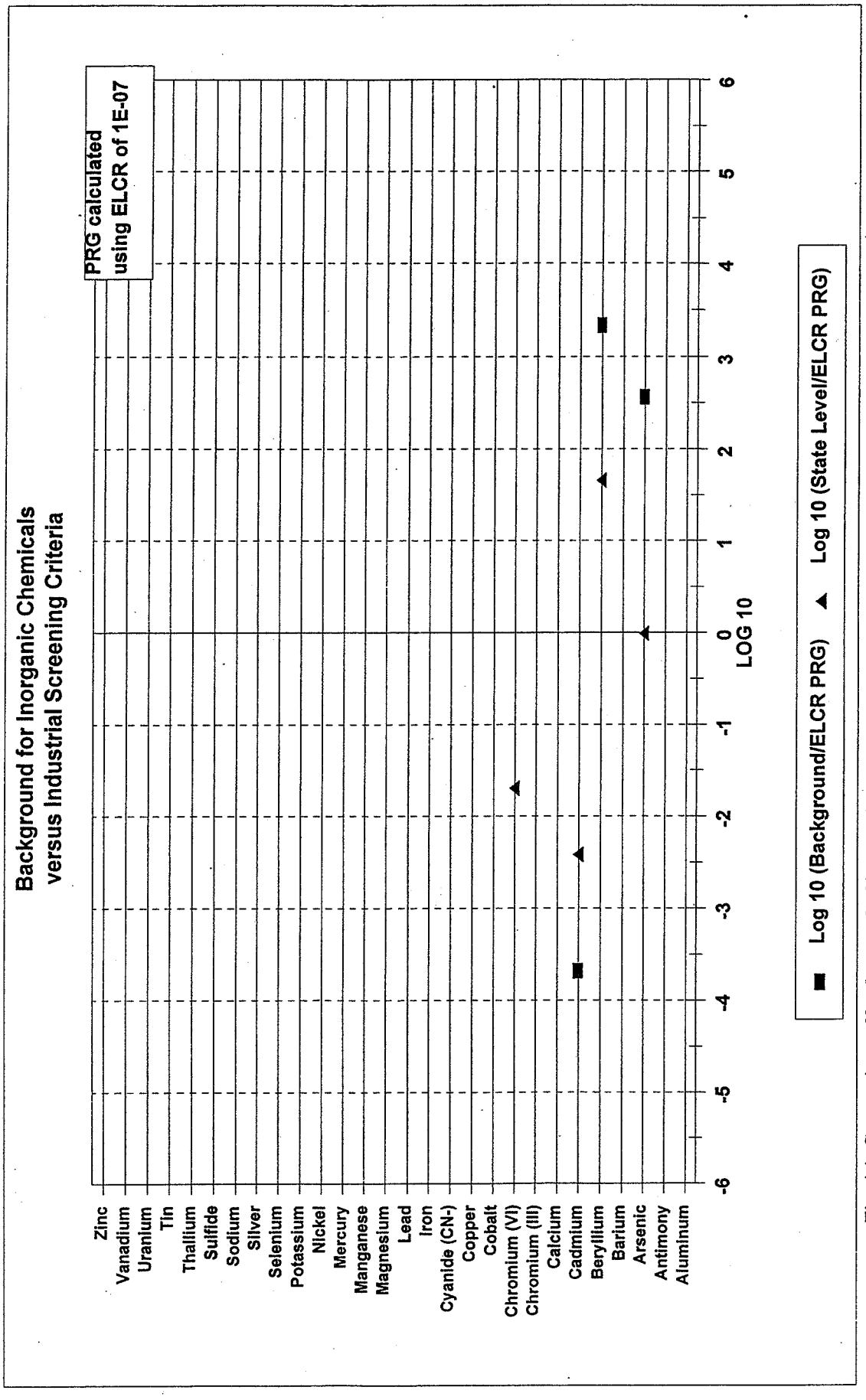


Fig. 4.1. Comparison of background of inorganic chemicals in surface soil to industrial PRGs - excess lifetime cancer risk.

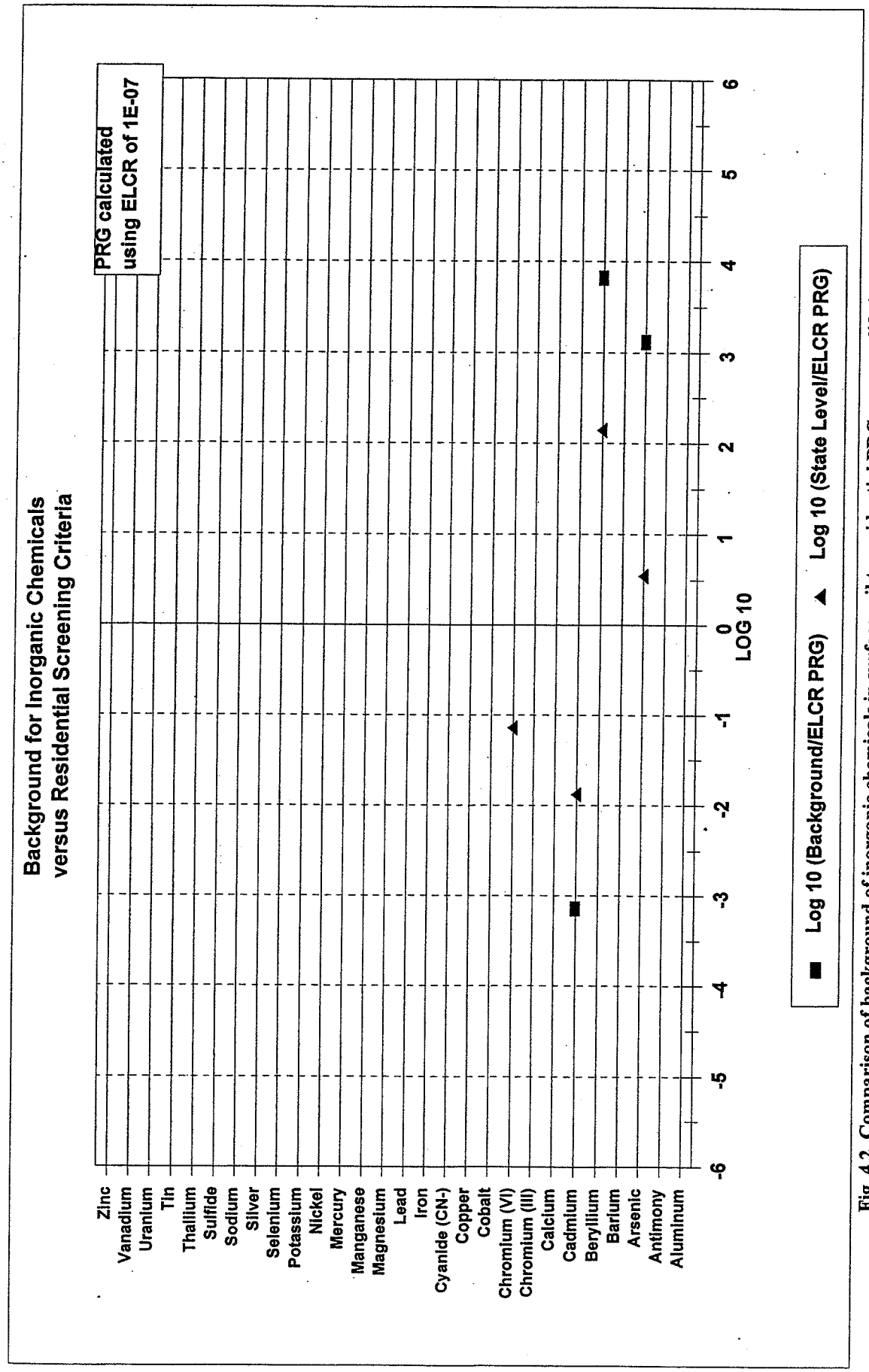


Fig. 4.2. Comparison of background of inorganic chemicals in surface soil to residential PRGs - excess lifetime cancer risk.

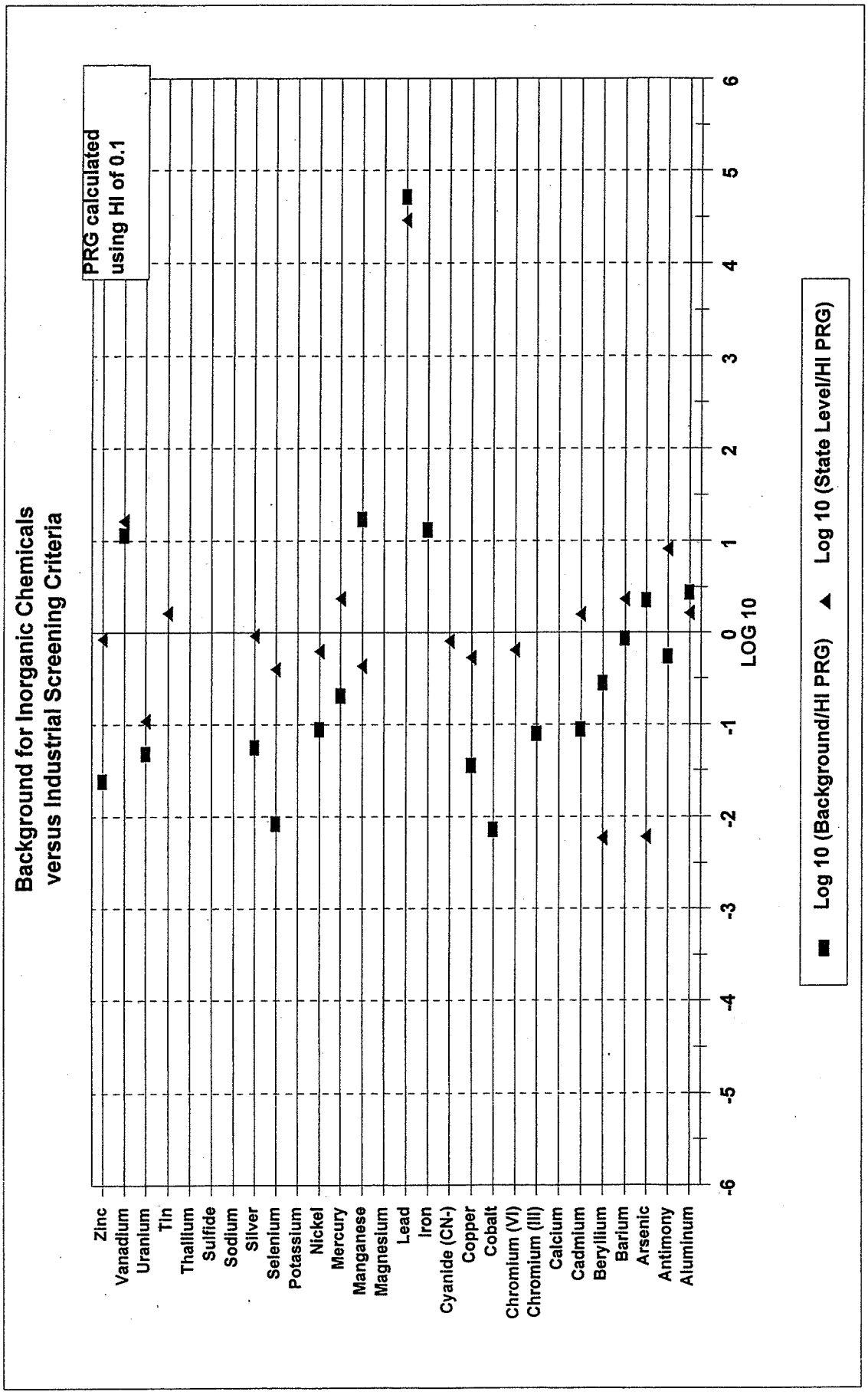


Fig. 4.3. Comparison of background of inorganic chemicals in surface soil to industrial PRGs - systemic hazard.

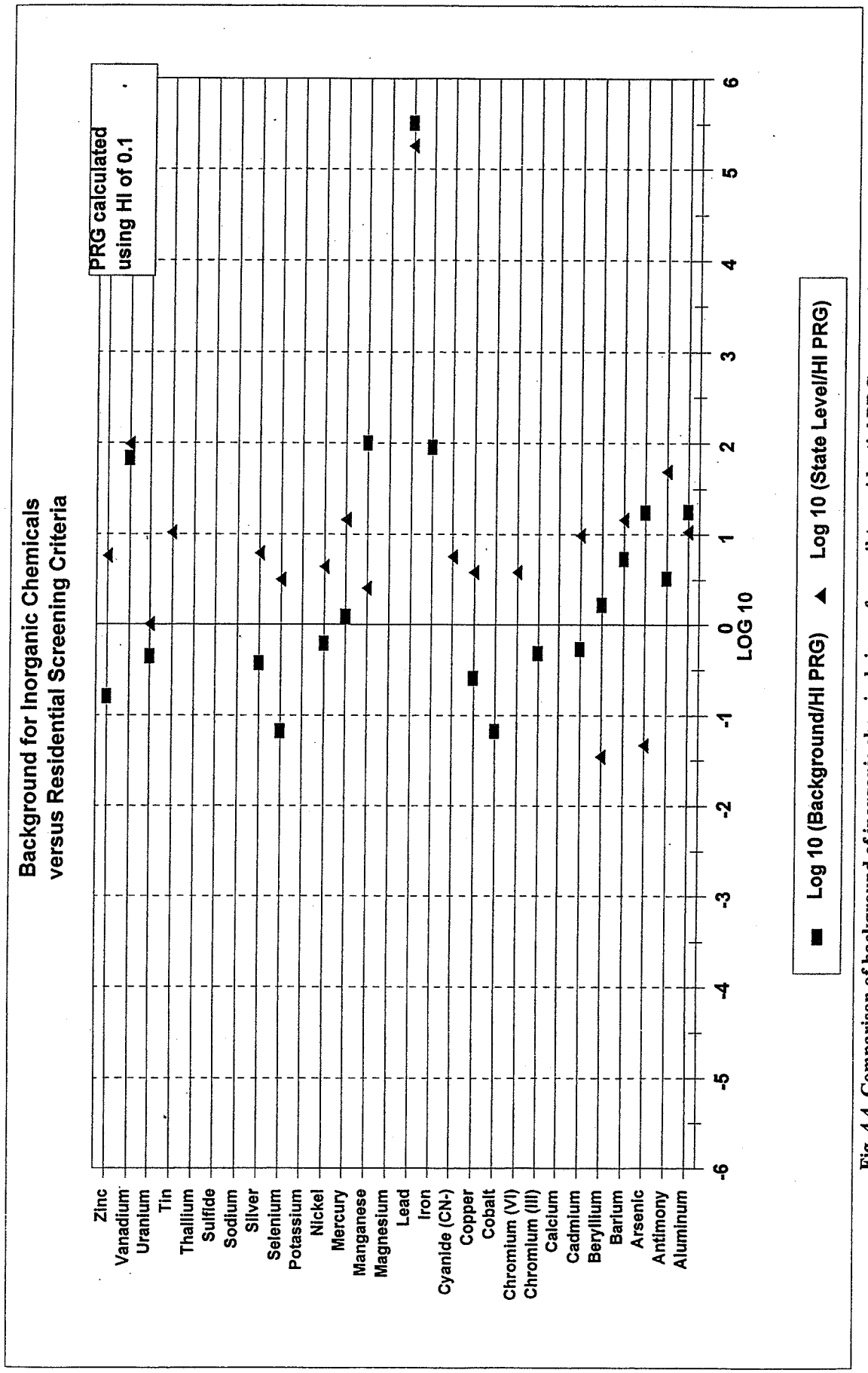


Fig. 4.4. Comparison of background of inorganic chemicals in surface soil to residential PRGs - systemic hazard.

lifetime cancer risk-based PRG, and exceeds, but not significantly, its industrial worker excess lifetime cancer risk-based PRG. Note, the background concentrations of beryllium and arsenic also exceed their respective state screening values.

As shown in Figs. 4.3 and 4.4, the background concentrations for Fe, Pb, Mn, and V significantly exceed their respective industrial systemic hazard-based PRG, and the background concentrations for Al, As, Fe, Pb, Mn, and V significantly exceed their respective residential systemic hazard-based PRG. Inorganic chemicals with a background concentration that exceeds, but not significantly, the industrial systemic hazard-based PRG are aluminum and arsenic. Inorganic chemicals with a background concentration that exceeds, but not significantly, the residential systemic hazard-based PRG are Sb, Ba, Be, and Hg.

It should be noted that although the background concentration for vanadium significantly exceeds its industrial and residential hazard-based PRGs, the background concentration in surface soil is less than its state screening level. Similarly, it should be noted that although the background concentrations of antimony and beryllium exceed their residential hazard-based PRGs, the background concentrations of these analytes are less than their state screening levels.

**Subsurface soil.** Table 4.2 and Figs. 4.5 (industrial use, excess lifetime cancer risk), 4.6 (residential use, excess lifetime cancer risk), 4.7 (industrial use, systemic hazard), and 4.8 (residential use, systemic hazard) present the comparison of selected background concentrations of inorganic chemicals in subsurface soil against human health risk-based screening criteria. In the table and figures, the background concentrations of Be, Tl, and U are the 95% upper tolerance bound on the 95$^{th}$ percentile concentration in B horizon soil as calculated in Chapter 3, and the background concentrations for antimony and cadmium are the maximum detection limits for antimony and cadmium in B horizon soil presented in Chapter 3. For all other inorganic chemicals, the background concentrations were taken from Table E.2 of DOE 1996a.

The background concentrations for Be, Tl, and U were set at their 95% upper tolerance bound on the 95$^{th}$ percentile concentration to remain consistent with the background threshold values selected in DOE 1996a. The reason for selecting the 95% upper tolerance bound of the 95$^{th}$ percentile concentration is discussed in Subsect. 2.1.2.2 of DOE 1996a. The background concentrations for antimony and cadmium were set at their maximum detection limits because these inorganic chemicals were not detected in B horizon soils collected during the background soils project (see Chapter 3).

As shown in Figs. 4.5 and 4.6, the background concentration of beryllium in subsurface soil significantly exceeds its industrial and residential excess lifetime cancer risk-based PRGs and exceeds the state screening value. Similarly, the background concentration of arsenic in subsurface soil nearly significantly exceeds its residential excess lifetime cancer risk-based PRG and exceeds the state screening level. The background concentration for arsenic in subsurface soil exceeds, but not significantly, its industrial excess lifetime cancer risk-based PRG.

As shown in Figs. 4.7 and 4.8, the background concentrations of Fe, Pb, and V significantly exceed their respective industrial systemic hazard-based PRG, and the background concentrations of Al, As, Fe, Pb, Mn, and V significantly exceed their respective residential systemic hazard-based PRG. Inorganic chemicals with a background concentration that exceeds, but not significantly, the industrial systemic hazard-based PRG are aluminum and arsenic. Inorganic chemicals with a subsurface soil background concentration that exceeds, but not significantly, the residential systemic hazard-based PRG are Sb, Ba, Be, and Cr (III).

**Table 4.2. Comparison of background concentrations of inorganic chemicals[a] in subsurface soil (more than 1 foot below ground surface) to human health screening criteria**

| Inorganic Chemical | Background Value[b] | Industrial Preliminary Remediation Goal[c] | | Residential Preliminary Remediation Goal[d] | | KyDEP Screening Value[e] |
|---|---|---|---|---|---|---|
| | | ELCR | HI | ELCR | HI | |
| Aluminum | 12,000 | --- | 4,700 | --- | 730 | 7,700 |
| Antimony[f] | 0.21 | --- | 0.38 | --- | 0.064 | 3.1 |
| Arsenic[g] | 7.9 | 0.033 | 5.3 | 0.0092 | 0.69 | 0.032 |
| Barium[h] | 170 | --- | 230 | --- | 37 | 530 |
| Beryllium[i] | 0.69 | 0.00031 | 2.4 | 0.00010 | 0.40 | 0.014 |
| Cadmium[j] | 0.21 | 1,000 | 2.4 | 290 | 0.39 | 3.8 |
| Calcium | 6,100 | --- | --- | --- | --- | --- |
| Chromium (III)[k] | 43 | --- | 200 | --- | 33 | --- |
| Chromium (VI) | [l] | 150 | 4.7 | 42 | 0.79 | 3.0 |
| Cobalt | 13 | --- | 1,900 | --- | 210 | --- |
| Copper[m] | 25 | --- | 530 | --- | 74 | 280 |
| Cyanide ($CN^-$) | [n] | --- | 160 | --- | 23 | 130 |
| Iron | 28,000 | --- | 2,100 | --- | 310 | --- |
| Lead[o] | 23 | --- | 0.00069 | --- | 0.00011 | 20 |
| Magnesium | 2,100 | --- | --- | --- | --- | --- |
| Manganese[p] | 820 | --- | 88 | --- | 15 | 38 |
| Mercury[q] | 0.13 | --- | 0.98 | --- | 0.16 | 2.3 |
| Nickel[r] | 22 | --- | 240 | --- | 34 | 150 |
| Potassium | 950 | --- | --- | --- | --- | --- |
| Selenium | 0.70 | --- | 95 | --- | 12 | 38 |
| Silver[s] | 2.7 | --- | 41 | --- | 6.1 | 38 |
| Sodium | 340 | --- | --- | --- | --- | --- |
| Sulfide | [l] | --- | --- | --- | --- | --- |
| Thallium | 0.34 | --- | --- | --- | --- | --- |
| Tin[t] | [l] | --- | 2,800 | --- | 440 | 4,600 |
| Uranium[u] | 4.6 | --- | 101 | --- | 11 | 11 |
| Vanadium[v] | 37 | --- | 3.3 | --- | 0.56 | 54 |
| Zinc[w] | 60 | --- | 2,700 | --- | 400 | 2,300 |

**Table 4.2. (continued)**

Notes: Cells with dashes (---) indicate data are not available or not applicable.
All values in mg/kg.

[a] Includes inorganic chemicals found on Target Analyte List as defined by EPA in 1988 CLP Statement of Work and RCRA Appendix IX list of constituents.

[b] Value for use in screening to determine if inorganic chemical was detected at naturally occurring concentration in subsurface soil. Details on the derivation of the background concentrations for antimony, beryllium, cadmium, thallium, and uranium are in Sect. 2 of this report. Details in the derivation of the background concentration of all other inorganic chemicals are in DOE 1996a.

[c] Industrial use preliminary remediation goal calculated using as target values an excess lifetime cancer risk (ELCR) of $1 \times 10^{-7}$ or a hazard index (HI) of 0.1. Preliminary remediation goals for all analytes, except that for lead, taken from Table 1 in Appendix 1 of DOE 1996b. The derivation of these values is in Appendix 2 of DOE 1996b. The value for lead was calculated using methods in Appendix 2 of DOE 1996b and toxicity values provided in comments on the WAG 17 report (KyDEP 1997).

[d] Residential use preliminary remediation goal calculated using as target values an excess lifetime cancer risk (ELCR) of $1 \times 10^{-7}$ or a hazard index (HI) of 0.1. Preliminary remediation goals for all analytes, except that for lead, taken from Table 2 in Appendix 1 of DOE 1996b. The derivation of these values is in Appendix 2 of DOE 1996b. The value for lead was calculated using methods in Appendix 2 of DOE 1996b and toxicity values provided in comments on the WAG 17 report (KyDEP 1997). Note, values for systemic hazard (i.e., HI values) are for a child aged 1 to 7 years.

[e] All values, except that for lead, are one-tenth of the soil screening value presented in KyDEP 1995. Use of one-tenth of the screening value for all but lead is in accordance with guidance on use of screening values in KyDEP 1995. Value for lead is the screening value and not one-tenth of the screening value. Use of this value is in accordance with guidance on use of screening values in KyDEP 1995.

[f] Industrial and residential PRGs are those for "Antimony (Metallic)" (Chemical Abstract Service Registry Number [CAS#] 7440-36-0) in DOE 1996b. KyDEP screening value is that for "Antimony and compounds."

[g] Industrial and residential PRGs are those for "Arsenic (Inorganic)" (CAS# 7440-38-2) in DOE 1996b. KyDEP screening value is that for "Arsenic and compounds."

[h] KyDEP screening value is that for "Barium and compounds."

[i] KyDEP screening value is that for "Beryllium and compounds."

[j] Industrial and residential PRGs are those for "Cadmium (water)" (CAS# 7440-43-9) in DOE 1996b. KyDEP screening value is that for Cadmium and compounds."

[k] Industrial and residential PRGs are those for "Chromium (III) (Insoluble Salts)" (CAS # 16065-83-1) in DOE 1996b.

[l] Data are not adequate to calculate a background concentration is soil for this analyte.

[m] KyDEP screening value is that for "Copper and compounds."

[n] Cyanide is not expected to be naturally occurring at PGDP; therefore a background value was not derived.

[o] See footnotes c, d, and e for additional information concerning the values for lead.

[p] Industrial and residential PRGs are those for Manganese (Water)" (CAS# 7439-96-5) in DOE 1996b. KyDEP screening value is that for "Manganese and compounds."

[q] Industrial and residential PRGs are those for "Mercury (Inorganic Salt)" (CAS# 7439-97-6) in DOE 1996b.

[r] Industrial and residential PRGs and those for "Nickel (Soluble Salts)" (CAS# 7440-02-0) in DOE 1996b.

[s] KyDEP screening value is that for "Silver and compounds."

[t] KyDEP screening value is that for "Tin and compounds."

[u] Industrial and residential PRGs and those for "Uranium (Soluble Salts)" (CAS# 7440-61-1) in DOE 1996b.

[v] Industrial and residential PRGs and those for "Vanadium (Metallic)" (CAS# 7440-62-2) in DOE 1996b.

[w] Industrial and residential PRGs and those for "Zinc (Metallic)" (CAS# 7440-66-6) in DOE 1996b.

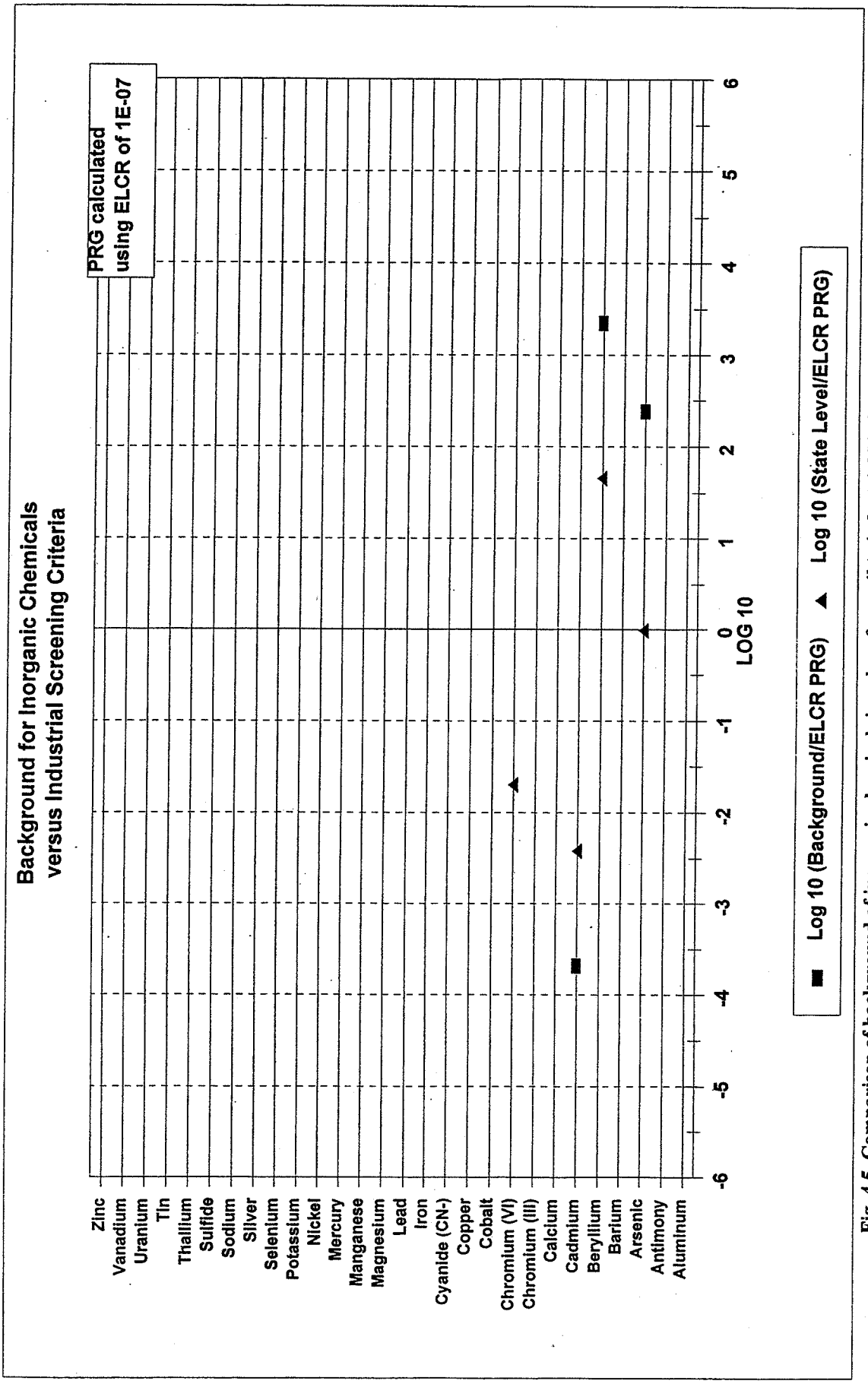


Fig. 4.5. Comparison of background of inorganic chemicals in subsurface soil to industrial PRGs - excess lifetime cancer risk.

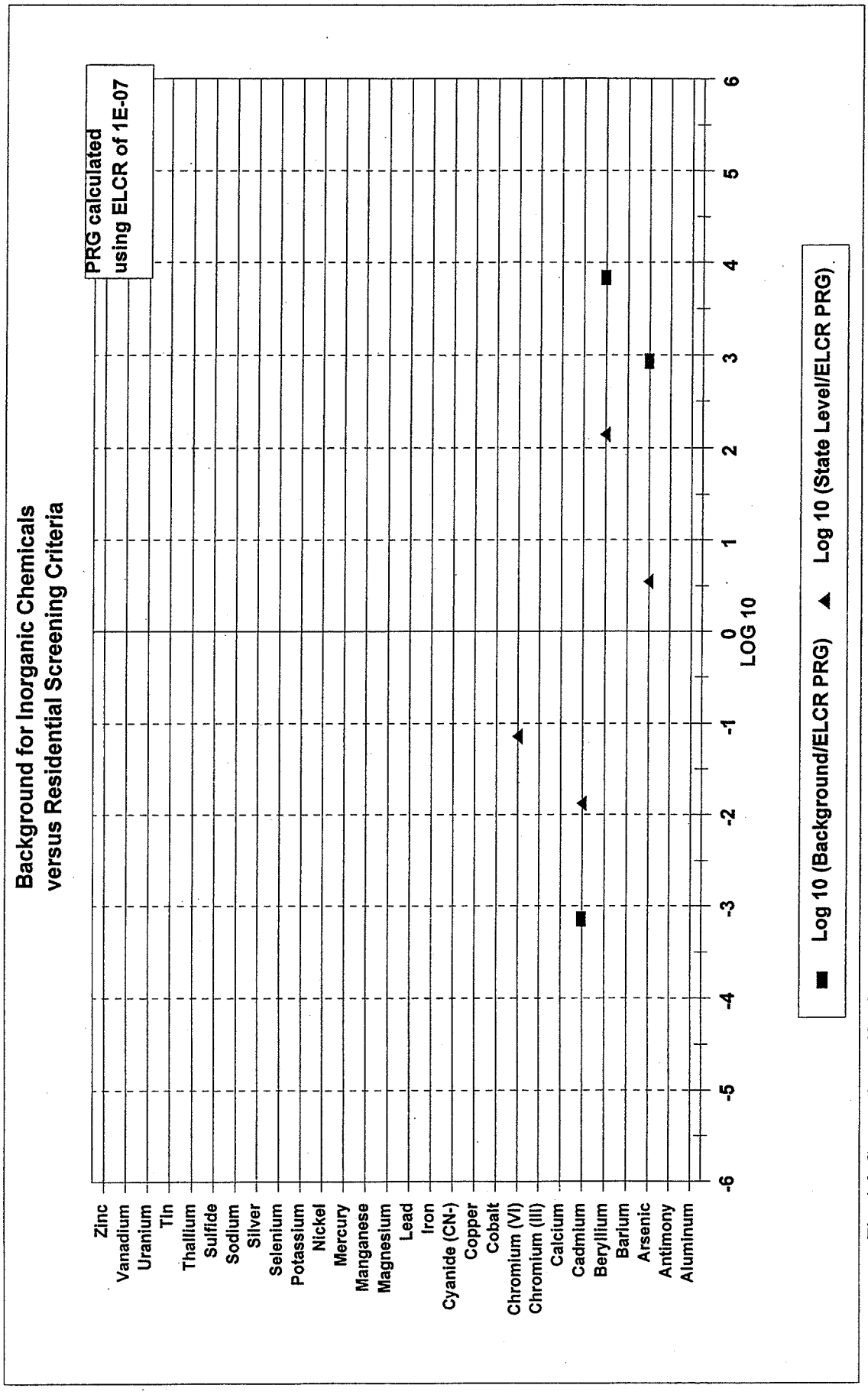


**Fig. 4.6. Comparison of background of inorganic chemicals in subsurface soil to residential PRGs - excess lifetime cancer risk.**

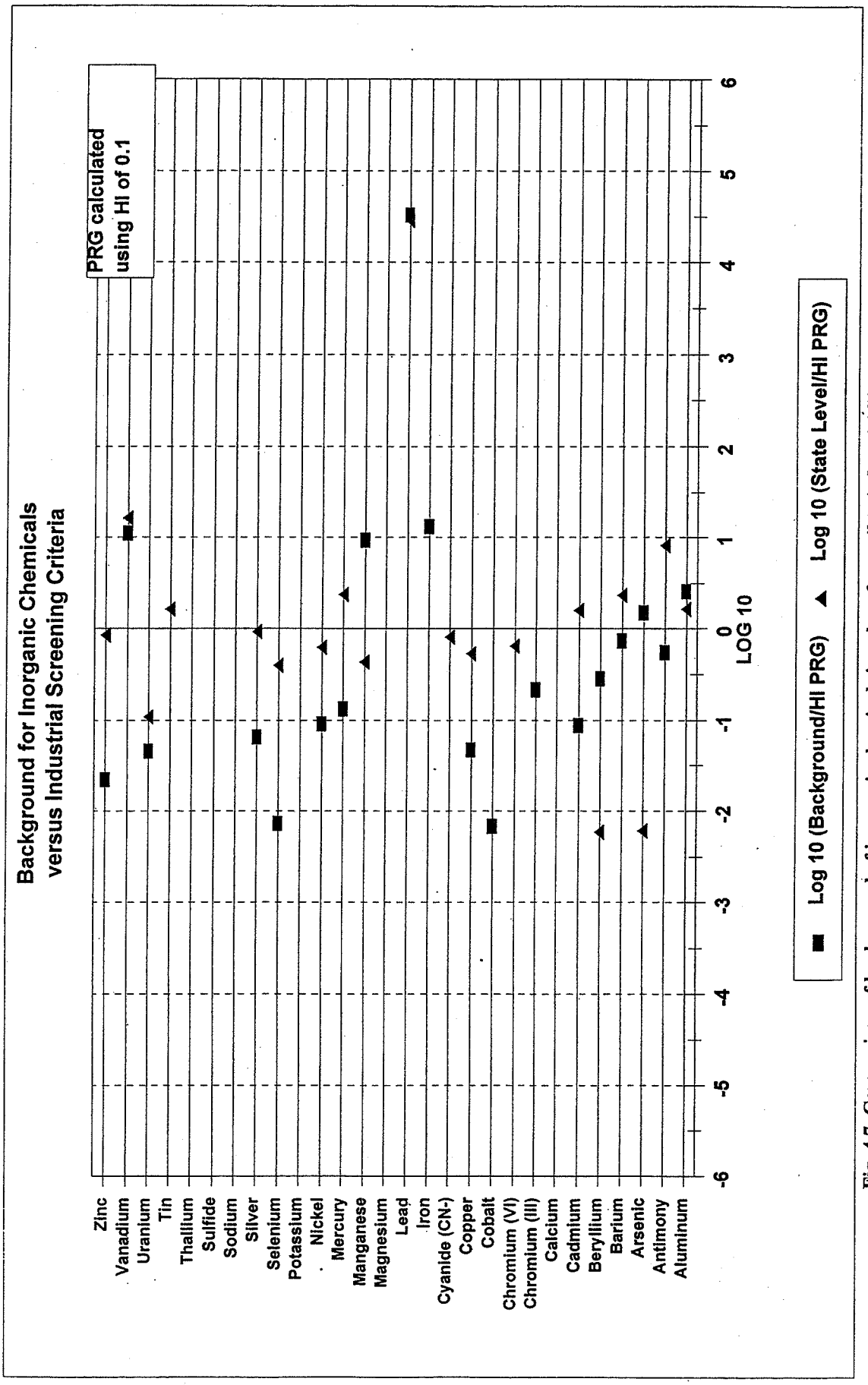


Fig. 4.7. Comparison of background of inorganic chemicals in subsurface soil to industrial PRGs - systemic hazard.

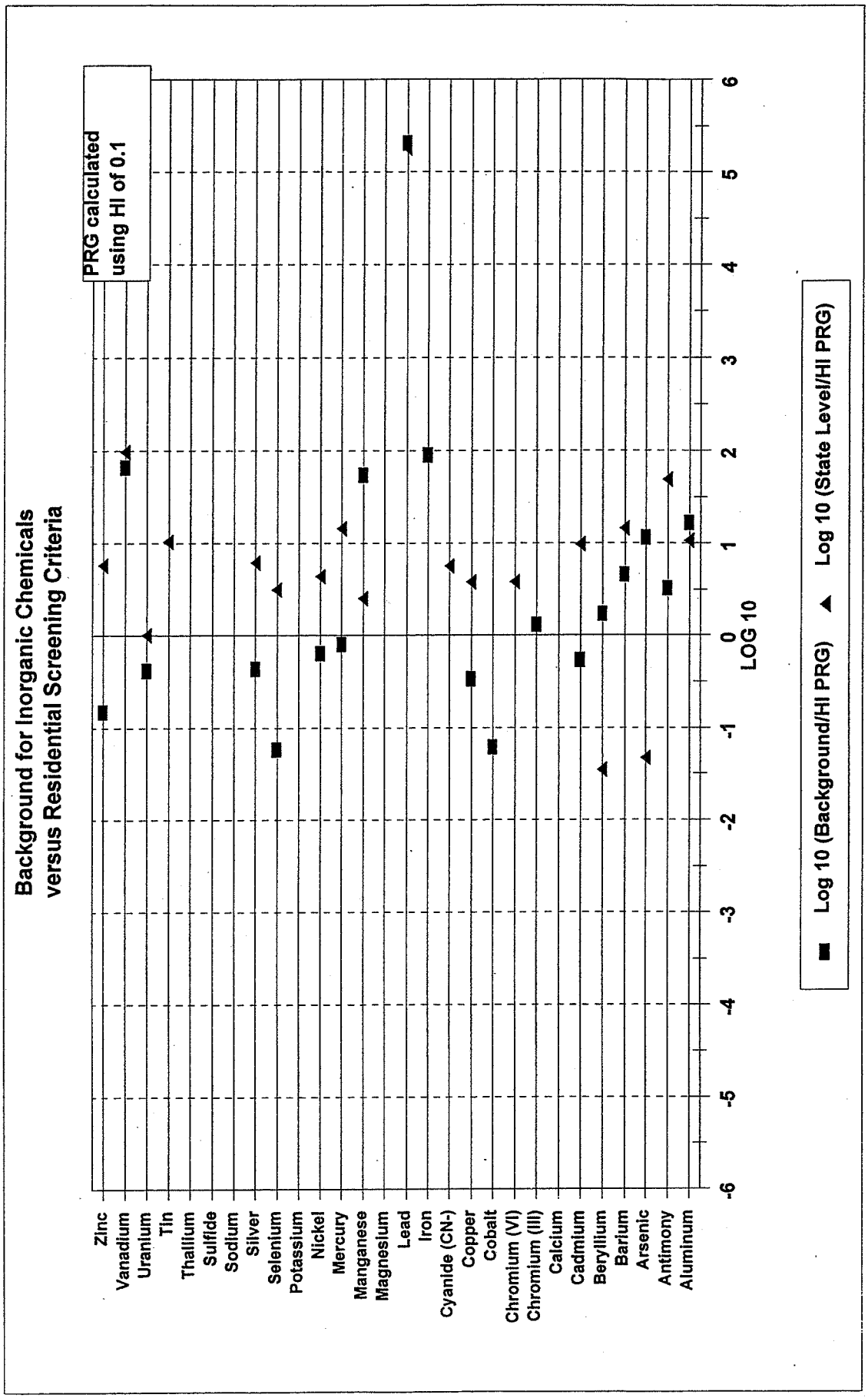


Fig. 4.8. Comparison of background of inorganic chemicals in subsurface soil to residential PRGs - systemic hazard.

It should be noted that although the background concentrations for vanadium in subsurface soil significantly exceed the industrial and residential hazard-based PRGs, its background concentration is less than its state screening level. Similarly, it should be noted that although the background concentrations of antimony and beryllium in subsurface soil exceed their residential hazard-based PRGs, the background concentrations of these analytes are less than their state screening levels.

#### 4.2.1.2 Radionuclides

**Interpretation of figures.** In the following discussions, in figures comparing the background concentrations of radionuclides and excess lifetime cancer risk-based PRGs, the background concentration of a radionuclide is said to significantly exceed its excess lifetime cancer risk-based PRG when the value indicated by the solid square is greater than 2. When the value indicated by the solid square is between 0 and 2, then the background concentration of the radionuclide is said to exceed, but not significantly, its respective excess lifetime cancer risk-based PRG. Finally, when the value indicated by the solid square is less than 0, then the radionuclide's background concentration is said to be less than its respective excess lifetime cancer risk-based PRG. (As with the inorganic chemicals, the value indicated by the solid square is equal to the logarithm of the background concentration of the radionuclide divided by the radionuclide's residential or industrial excess lifetime cancer risk-based PRG. A full discussion of the derivation and interpretation of these figures is in Appendix E of DOE 1996d.) Note, when the value indicated by the solid square is greater than 2, the background concentration is said to significantly exceed its excess lifetime cancer risk-based PRG because risk calculated for a residential or industrial receptor directly contacting soil containing the radionuclide alone at the background concentration would be greater than $1 \times 10^{-4}$, if the risk calculation used the default exposure factors used to calculate the excess lifetime cancer risk-based PRG.

The benchmark value selected in this discussion for determining if a radionuclide significantly exceeds its risk-based PRG differs from that for inorganic chemicals. This is because the target risk on which the radionuclide excess lifetime cancer risk PRG is based is $1 \times 10^{-6}$ versus the $1 \times 10^{-7}$ used for inorganic chemicals. The variation between the target excess lifetime cancer risk used to calculate the inorganic chemical risk-based PRGs and that used to calculate the radionuclide risk-based PRGs is discussed in DOE 1996c.

**Surface soil.** Table 4.3 and Figs. 4.9 (industrial use, excess lifetime cancer risk) and 4.10 (residential use, excess lifetime cancer risk) present the comparison of the selected background concentrations of radionuclides in surface soil against human health risk-based screening criteria. In the table and figures, all background values, except that for $^{235}U$, are the 95% upper tolerance bound on the 95$^{th}$ percentile concentration in A horizon soil. The background value for $^{235}U$ is the maximum detection limit for $^{235}U$ in A horizon soil presented in Chapter 3.

The background concentrations for all background values, except that for $^{235}U$, were set at their 95% upper tolerance bound on the 95$^{th}$ percentile concentration to remain consistent with the background threshold values selected in DOE 1996a. The reason for selecting the 95% upper tolerance bound in the 95$^{th}$ percentile concentration is discussed in Subsect. 2.1.2.2 of DOE 1996a. The background concentration for $^{235}U$ was set at its maximum detection limit because this radionuclide was not detected in A horizon soils collected during the background soils project (see Chapter 3).

**Table 4.3. Comparison of background concentrations of radionuclides in surface soil (0 to 1 foot below ground surface) to human health screening criteria**

| Radionuclide | Background Value[a] | Industrial Preliminary Remediation Goal[b] | | Residential Preliminary Remediation Goal[c] | | KyDEP Screening Value[d] |
|---|---|---|---|---|---|---|
| | | ELCR | HI | ELCR | HI | |
| Cesium-137 | 0.49 | 0.11* | --- | 0.016* | --- | --- |
| Neptunium-237 | 0.10 | 0.45* | --- | 0.068* | --- | --- |
| Plutonium-238 | 0.073 | 11 | --- | 2.1 | --- | --- |
| Plutonium-239[e] | 0.025 | 10 | --- | 2.0 | --- | --- |
| Potassium-40 | 16 | 0.36 | --- | 0.053 | --- | --- |
| Radium-226 | 1.5 | 0.032* | --- | 0.0048* | --- | --- |
| Strontium-90 | 4.7 | 57* | --- | 11* | --- | --- |
| Technetium-99 | 2.5 | 2,270 | --- | 440 | --- | --- |
| Thorium-228 | 1.6 | 0.22* | --- | 0.032* | --- | --- |
| Thorium-230 | 1.5 | 81 | --- | 16 | --- | --- |
| Thorium-232 | 1.5 | 92 | --- | 18 | --- | --- |
| Uranium-234[f] | 2.5 | 70 | --- | 14 | --- | --- |
| Uranium-235 | 0.14 | 0.82* | --- | 0.12* | --- | --- |
| Uranium-238 | 1.2 | 3.9* | --- | 0.58* | --- | --- |

Notes: Cells with dashes (---) indicate data are not available or not applicable.
Values marked with asterisk (*) were derived using "+D" toxicity values in Appendix 1 of DOE 1996b.
All values in pCi/g.

[a] Value for use in screening to determine if radionuclide was detected at naturally occurring concentration in surface soil. Details on the derivation of the background concentrations are in Sect. 2 of this report.

[b] Industrial use preliminary remediation goal calculated using as target values an excess lifetime cancer risk (ELCR) of $1 \times 10^{-6}$. All values taken from Table 1 in Appendix 1 of DOE 1996b. The derivation of these values is in Appendix 2 of DOE 1996b.

[c] Residential use preliminary remediation goal calculated using as target values an excess lifetime cancer risk (ELCR) of $1 \times 10^{-6}$. All values taken from Table 2 in Appendix 1 of DOE 1996b. The derivation of these values is in Appendix 2 of DOE 1996b.

[d] KyDEP 1995 does not contain any screening values for radionuclides.

[e] Background value shown is that for plutonium-239/240 from Sect. 3.

[f] Background value shown is that for uranium-233/234 from Sect. 3.

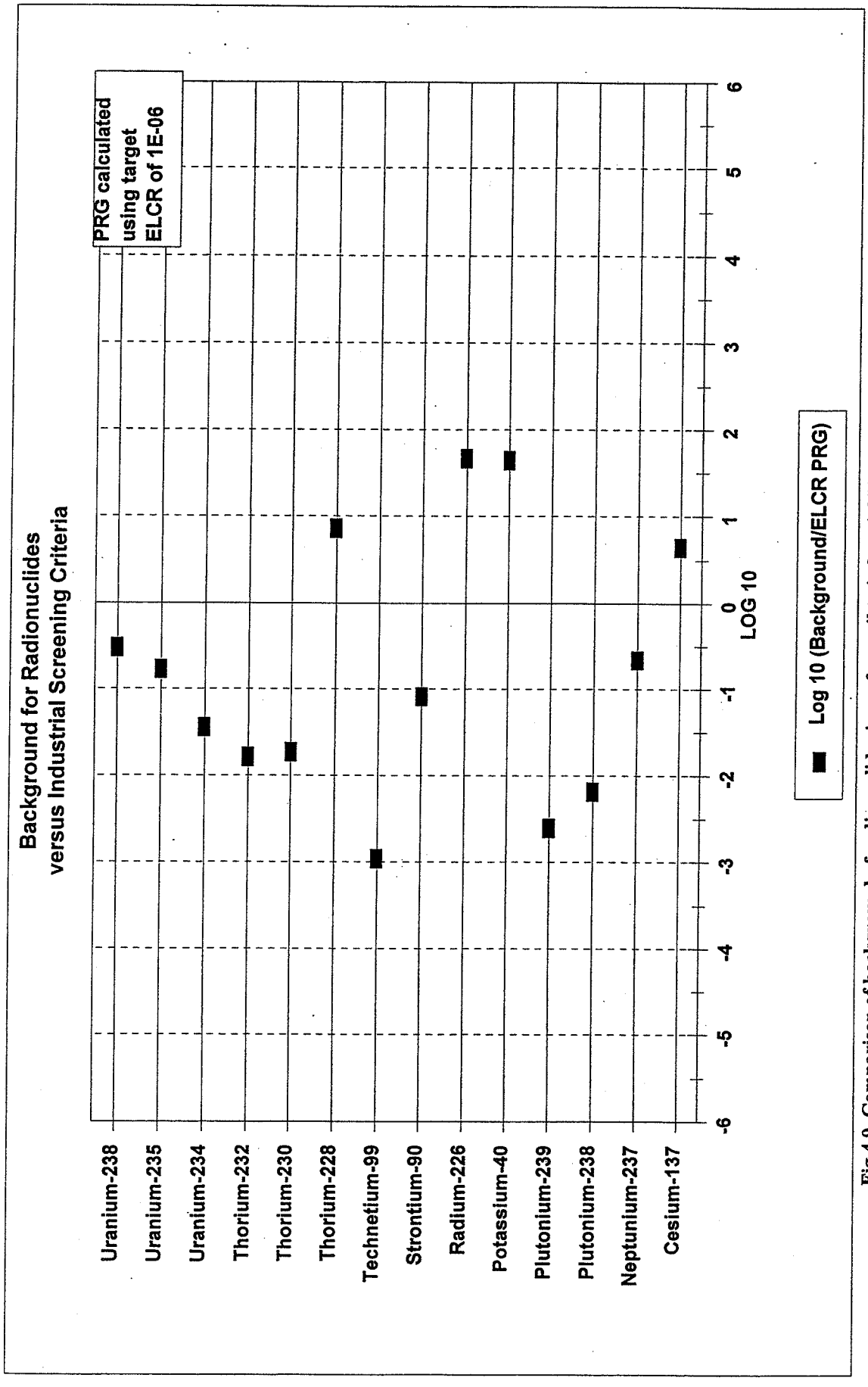


Fig.4.9. Comparison of background of radionuclides in surface soil to industrial PRGs - excess lifetime cancer risk.

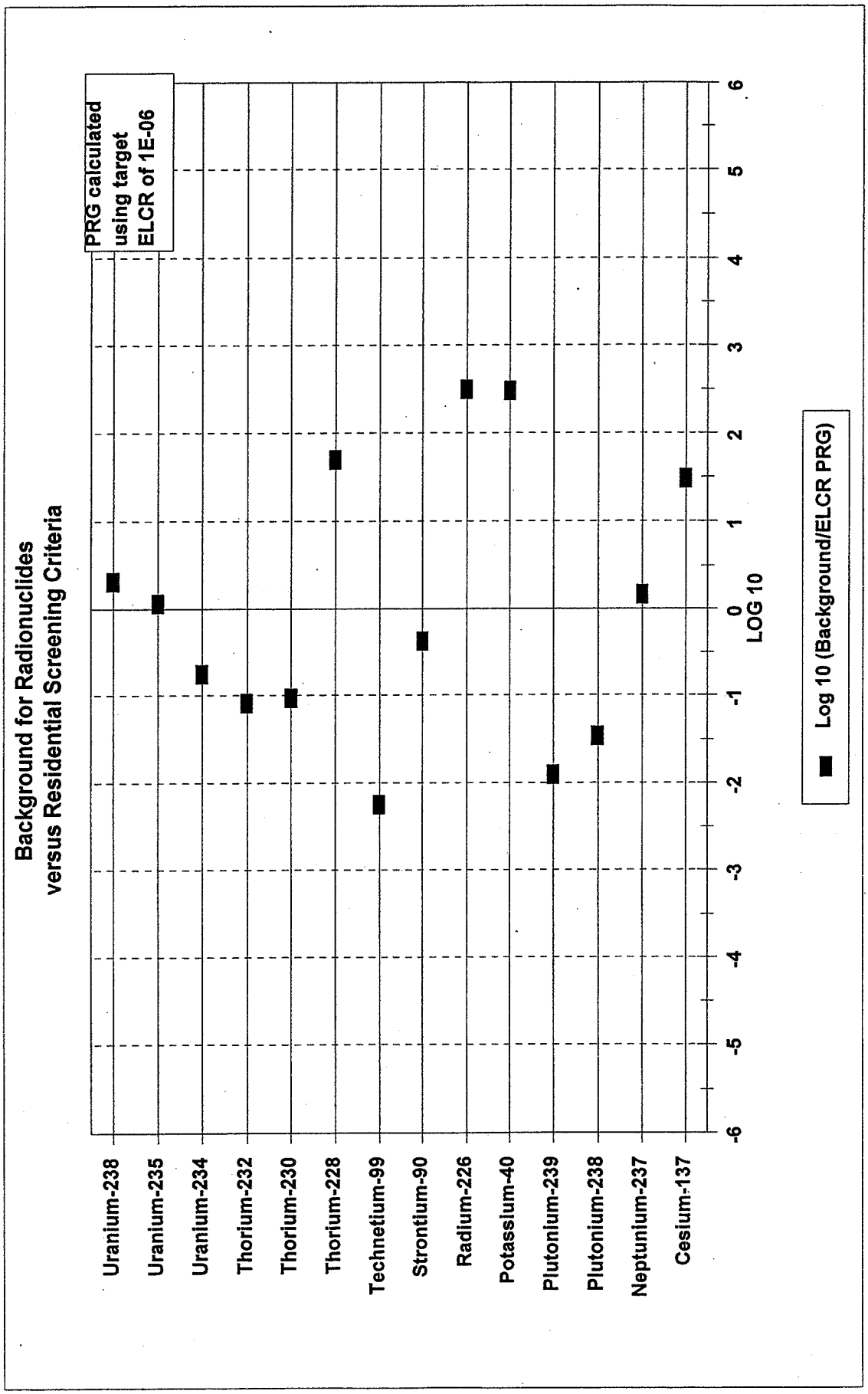


Fig.4.10. Comparison of background of radionuclides in surface soil to residential PRGs - excess lifetime cancer risk.

As shown in Figs. 4.9 and 4.10, the background concentrations of $^{40}K$ and $^{226}Ra$ significantly exceed their respective residential excess lifetime cancer risk-based PRGs. However, no radionuclides have a background concentration in surface soil that significantly exceeds its respective industrial excess lifetime cancer risk-based PRG. In addition, as shown in Figs. 4.9 and 4.10, the background concentrations of $^{137}Cs$, $^{40}K$, $^{226}Ra$, and $^{228}Th$ exceed, but not significantly, their respective industrial risk-based PRGs, and the background concentrations of $^{137}Cs$, $^{237}Np$, and $^{228}Th$ exceed, but not significantly, their respective residential risk-based PRG.

**Subsurface soil.** Table 4.4 and Figs. 4.11 (industrial use, excess lifetime cancer risk) and 4.12 (residential use, excess lifetime cancer risk) present the comparison of the selected background concentrations of radionuclides in subsurface soil against human health risk-based screening criteria. In the table and figures, all background values, except that for $^{235}U$ are the 95% upper tolerance bound on the 95$^{th}$ percentile concentration in B horizon soil. The background value for $^{235}U$ is the maximum detection limit for $^{235}U$ in B horizon soil.

The background concentrations for all background values, except that for $^{235}U$, were set at their 95% upper tolerance bound on the 95$^{th}$ percentile concentration to remain consistent with the background threshold values selected in DOE 1996a. The reason for selecting the 95% upper tolerance bound in the 95$^{th}$ percentile concentration is discussed in Subsect. 2.1.2.2 of DOE 1996a. The background concentration for $^{235}U$ was set at its maximum detection limit because this radionuclide was not detected in B horizon soils collected during the background soils project (see Chapter 3).

As shown in Figs. 4.11 and 4.12, the background concentrations of $^{40}K$ and $^{226}Ra$ significantly exceed their respective residential excess lifetime cancer risk-based PRGs. However, no radionuclides have a background concentration in subsurface soil that significantly exceeds its respective industrial risk-based PRG. Additionally, as shown in Figs. 4.11 and 4.12, the background concentrations of $^{137}Cs$, $^{40}K$, $^{226}Ra$, and $^{228}Th$ exceed, but not significantly, their respective industrial risk-based PRG, and the background concentrations of $^{137}Cs$, $^{228}Th$, $^{235}U$, and $^{238}U$ exceed, but not significantly, their respective residential risk-based PRG.

#### 4.2.1.3 Summary of comparisons to human health risk-based screening criteria

As discussed in Subsects. 4.2.1.1 and 4.2.1.2, several inorganic chemicals and radionuclides have background concentrations that exceed one or more of their PRGs. This result is summarized in the following text and in Table 4.5.

**Analytes with selected background concentrations in surface soil that significantly exceed risk-based or hazard-based PRGs**—Al (residential only), As (residential only), Be (industrial and residential), Fe (industrial and residential), Pb (industrial and residential), Mn (industrial and residential), V (industrial and residential), $^{40}K$ (residential only), $^{226}Ra$ (residential only).

**Analytes with selected background concentrations in surface soil that exceed, but not significantly, risk-based or hazard-based PRGs**—Al (industrial only), Sb (residential only), As (industrial only), Ba (residential only), Hg (residential only), $^{137}Cs$ (industrial and residential), $^{237}Np$ (residential only), $^{40}K$ (industrial only), $^{226}Ra$ (industrial only), $^{228}Th$ (industrial and residential), $^{235}U$ (residential only), and $^{238}U$ (residential only).

**Table 4.4. Comparison of background concentrations of radionuclides in subsurface soil (more than 1 foot below ground surface) to human health screening criteria**

| Radionuclide | Background Value[a] | Industrial Preliminary Remediation Goal[b] | | Residential Preliminary Remediation Goal[c] | | KyDEP Screening Value[d] |
|---|---|---|---|---|---|---|
| | | ELCR | HI | ELCR | HI | |
| Cesium-137 | 0.28 | 0.11* | --- | 0.016* | --- | --- |
| Neptunium-237 | --- | 0.45* | --- | 0.068* | --- | --- |
| Plutonium-238 | --- | 11 | --- | 2.1 | --- | --- |
| Plutonium-239 | --- | 10 | --- | 2.0 | --- | --- |
| Potassium-40 | 16 | 0.36 | --- | 0.053 | --- | --- |
| Radium-226 | 1.5 | 0.032* | --- | 0.0048* | --- | --- |
| Strontium-90 | --- | 57* | --- | 11* | --- | --- |
| Technetium-99 | 2.8 | 2,270 | --- | 440 | --- | --- |
| Thorium-228 | 1.6 | 0.22* | --- | 0.032* | --- | --- |
| Thorium-230 | 1.4 | 81 | --- | 16 | --- | --- |
| Thorium-232 | 1.5 | 92 | --- | 18 | --- | --- |
| Uranium-234[e] | 2.4 | 70 | --- | 14 | --- | --- |
| Uranium-235 | 0.14 | 0.82* | --- | 0.12* | --- | --- |
| Uranium-238 | 1.2 | 3.9* | --- | 0.58* | --- | --- |

Notes: Cells with dashes (---) indicate data are not available or not applicable.
Values marked with asterisk (*) were derived using "+D" toxicity values in Appendix 1 of DOE 1996b.
All values in pCi/g.

[a] Value for use in screening to determine if radionuclide was detected at naturally occurring concentration in surface soil. Details on the derivation of the background concentrations are in Sect. 2 of this report.

[b] Industrial use preliminary remediation goal calculated using as target values an excess lifetime cancer risk (ELCR) of $1 \times 10^{-6}$. All values taken from Table 1 in Appendix 1 of DOE 1996b. The derivation of these values is in Appendix 2 of DOE 1996b.

[c] Residential use preliminary remediation goal calculated using as target values an excess lifetime cancer risk (ELCR) of $1 \times 10^{-6}$. All values taken from Table 2 in Appendix 1 of DOE 1996b. The derivation of these values is in Appendix 2 of DOE 1996b.

[d] KyDEP 1995 does not contain any screening values for radionuclides.

[e] Background value shown is that for uranium-233/234 from Sect. 3.

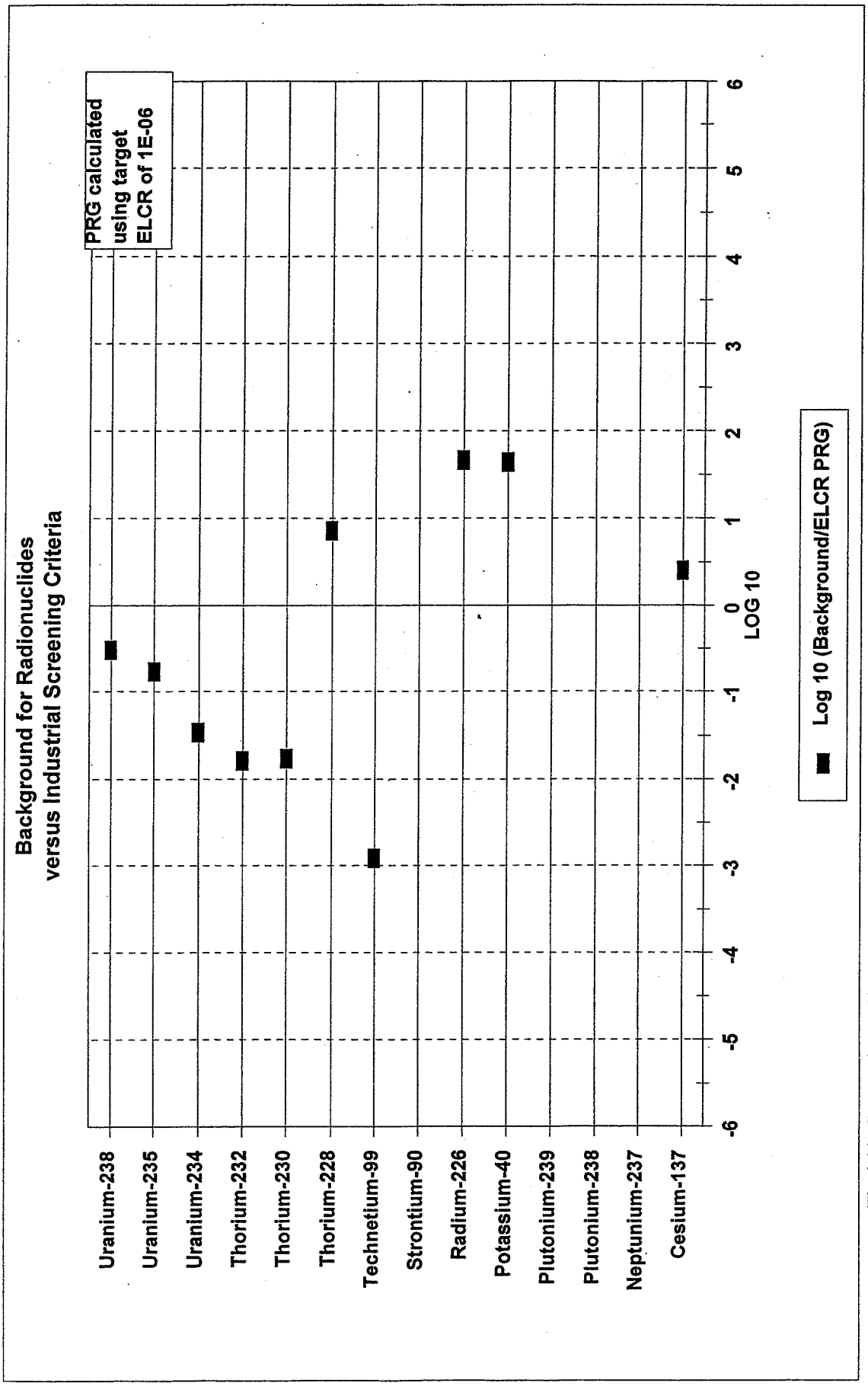


Fig.4.11. Comparison of background of radionuclides in subsurface soil to industrial PRGs - excess lifetime cancer risk.

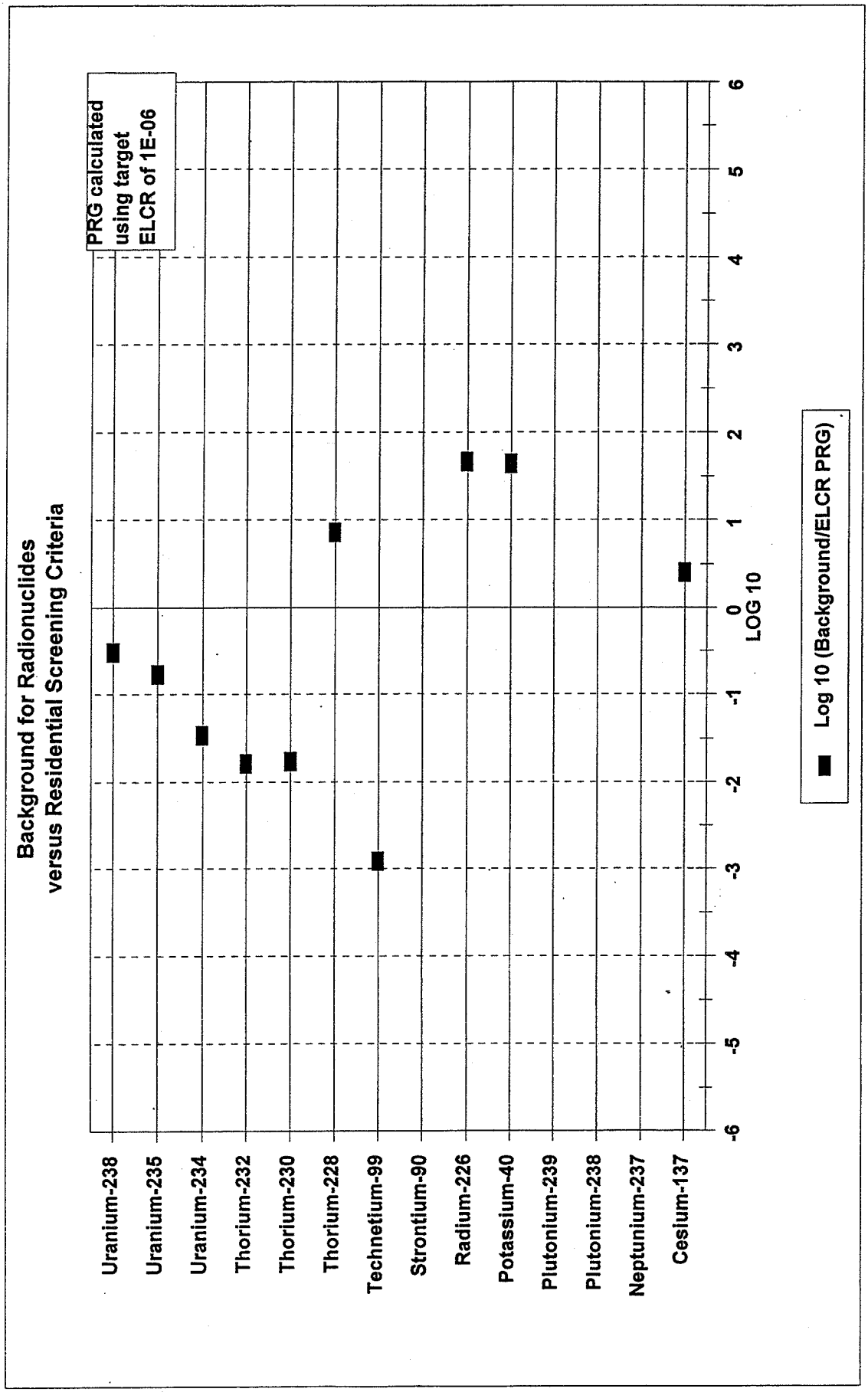


Fig.4.12. Comparison of background of radionuclides in subsurface soil to residential PRGs - excess lifetime cancer risk.

**Table 4.5. Summary of comparison of background concentrations of selected analytes[a] in surface and subsurface soil to human health screening criteria**

| Analyte | Industrial Preliminary Remediation Goal | | Residential Preliminary Remediation Goal | | KyDEP Screening Value | |
|---|---|---|---|---|---|---|
| | Surface | Subsurface | Surface | Subsurface | Surface | Subsurface |
| Inorganic Chemicals | | | | | | |
| Aluminum | + | + | +++ | +++ | + | + |
| Antimony | | | + | + | | |
| Arsenic | + | + | +++ | +++ | + | + |
| Barium | | | + | + | | |
| Beryllium | +++ | +++ | +++ | +++ | + | + |
| Chromium (III) | | | | + | NV | NV |
| Iron | +++ | +++ | +++ | +++ | NV | NV |
| Lead | +++ | +++ | +++ | +++ | + | + |
| Manganese | +++ | + | +++ | +++ | + | + |
| Mercury | | | + | | | |
| Vanadium | +++ | +++ | +++ | +++ | | |
| Radionuclides | | | | | | |
| $^{137}Cs$ | + | + | + | + | NV | NV |
| $^{40}K$ | + | + | +++ | +++ | NV | NV |
| $^{237}Np$ | | | + | | | |
| $^{226}Ra$ | + | + | +++ | +++ | NV | NV |
| $^{228}Th$ | + | + | + | + | NV | NV |
| $^{235}U$ | | | + | + | NV | NV |
| $^{238}U$ | | | + | + | NV | NV |

Notes: "+++" indicates that the background concentration significantly exceeds the PRG.
"+" indicates that the background concentration exceeds the PRG.
"NV" indicates that there is no value available for screening the background concentration of the respective analyte.
Blank cells indicate that the background concentration of the analyte did not exceed the respective PRG.

[a] Only analytes with a background concentration that exceeds one or more human health screening criteria are listed.

**Analytes with selected background concentrations in surface soil that do not exceed any risk-based or hazard-based PRGs**—Cd, Ca, Cr (III), Cr (VI), Co, Cu, cyanide, Mg, Ni, K, Se, Ag, Na, Tl, Sn, U, Zn, $^{238}$Pu, $^{239}$Pu, $^{90}$Sr, $^{99}$Tc, $^{230}$Th, $^{232}$Th, and $^{234}$U. [Note, surface soil background concentrations for chromium (VI) , cyanide, sulfide, and tin are effectively their sample quantitation limit because specific background values for these analytes were not derived.]

**Analytes with selected background concentrations in subsurface soil that significantly exceed risk-based or hazard-based PRGs**—Al (residential only), As (residential only), Be (industrial and residential), Fe (industrial and residential), Pb (industrial and residential), Mn (residential only), V (industrial and residential), $^{40}$K (residential only), and $^{226}$Ra (residential only).

**Analytes with selected background concentrations in subsurface soil that exceed, but not significantly, risk-based or hazard-based PRGs**—Al (industrial only), Sb (residential only), As (industrial only), Ba (residential only), Cr (III) (residential only), and Mn (industrial only), $^{137}$Cs (industrial and residential), $^{40}$K (industrial only), $^{226}$Ra (industrial only), $^{228}$Th (industrial and residential), $^{235}$U (residential only), and $^{238}$U (residential only).

**Analytes with selected background concentrations in subsurface soil that do not exceed any risk-based or hazard-based PRGs**—Cd, Ca, Cr (VI), Co, Cu, cyanide, Mg, Hg, Ni, K, Se, Ag, Na, sulfide, Tl, Sn, U, Zn, $^{237}$Np, $^{238}$Pu, $^{239}$Pu, $^{90}$Sr, $^{99}$Tc, $^{230}$Th, $^{232}$Th, and $^{234}$U. [Note, subsurface soil background concentrations for chromium (VI) , cyanide, sulfide, tin, $^{237}$Np, $^{238}$Pu, $^{239}$Pu, and $^{90}$Sr are effectively their sample quantitation limit because specific background values for these analytes were not derived.]

### 4.2.2 Comparisons to Ecological Screening Criteria

In this subsection, the selected background concentrations for inorganic chemicals in surface and subsurface soil are compared against ecological screening criteria (i.e., PRGs) taken from Energy Systems 1996. The methods used to derive these screening criteria are presented in Energy Systems 1996. Background concentrations for radionuclides are not compared against ecological screening criteria because ecological PRGs for radionuclides in soil currently do not exist.

Table 4.6 and Figs. 4.13, 4.14, and 4.15 present comparisons between the selected background concentrations in surface soil and subsurface soil against soil and sediment ecological PRGs. Sediment PRGs are considered when examining surface soil background concentrations because surface soil background concentrations are likely to be used as surrogates for sediment background during risk evaluations at PGDP. As shown in Figs. 4.13 and 4.15, the surface and subsurface soil background concentrations of Al, As, Cr (III), Fe, Mn, Hg, Ag, V, and Zn exceed their respective soil ecological PRG. However, as shown in Fig. 4.14, silver is the only inorganic chemical with a surface soil background concentration that exceeds a sediment ecological PRG.

## 4.3 USE OF BACKGROUND CONCENTRATIONS IN FUTURE RISK EVALUATIONS AND ASSESSMENTS AND UNCERTAINTIES

In this part of the risk analysis, the use of the background concentrations in future risk evaluations and assessments and the uncertainties presented by their use are discussed. This discussion is necessary because background concentrations will be used in several phases of the

**Table 4.6. Comparison of background concentrations of inorganic chemicals[a] to ecological endpoint screening criteria**

| Inorganic Chemical | Background Value[b] | | Ecological Preliminary Remediation Goal[c] | |
|---|---|---|---|---|
| | Surface | Subsurface | Soil | Sediment |
| Aluminum | 13,000 | 12,000 | 50 | --- |
| Antimony | 0.21 | 0.21 | 5 | --- |
| Arsenic | 12 | 7.9 | 2.66 | 42 |
| Barium | 200 | 170 | 208 | --- |
| Beryllium | 0.67 | 0.69 | 10 | --- |
| Cadmium | 0.21 | 0.21 | 3 | 4.2 |
| Calcium | 200,000 | 6,100 | --- | --- |
| Chromium (III)[d] | 16 | 43 | 0.4 | 160 |
| Chromium (VI)[d] | ---[f] | ---[f] | 0.4 | 160 |
| Cobalt | 14 | 13 | 20 | --- |
| Copper | 19 | 25 | 50 | 110 |
| Cyanide (CN-)[e] | --- | --- | --- | --- |
| Iron | 28,000 | 28,000 | 200 | --- |
| Lead | 36 | 23 | 50 | 110 |
| Magnesium | 7,700 | 2,100 | --- | --- |
| Manganese | 1,500 | 820 | 100 | --- |
| Mercury | 0.2 | 0.13 | 0.0185 | 0.7 |
| Nickel | 21 | 22 | 24 | 43 |
| Potassium | 1,300 | 950 | --- | --- |
| Selenium | 0.8 | 0.7 | 0.79 | --- |
| Silver | 2.3 | 2.7 | 2 | 1.8 |
| Sodium | 320 | 340 | --- | --- |
| Sulfide[f] | --- | --- | --- | --- |
| Thallium | 0.21 | 0.34 | 1 | --- |
| Tin[f] | --- | --- | 50 | --- |
| Uranium | 4.9 | 4.6 | 5 | --- |
| Vanadium | 38 | 37 | 2 | --- |
| Zinc | 65 | 60 | 26.3 | 270 |

Notes: Cells with dashes (---) indicate data are not available or not applicable.
All values in mg/kg.

[a] Includes inorganic chemicals found on Target Analyte List as defined by EPA in 1988 CLP Statement of Work and RCRA Appendix IX list of constituents.

[b] Value for use in screening to determine if inorganic chemical was detected at naturally occurring concentration in surface or subsurface soil. Details on the derivation of the background concentrations for antimony, beryllium, cadmium, thallium, and uranium are in Sect. 2 of this report. Details on the derivation of the background concentration for all other inorganic chemicals are in DOE 1996a.

[c] All preliminary remediation goals (PRGs) for ecological endpoints taken from Energy Systems 1996a. This report should be consulted for information concerning the derivation of these values.

[d] Data are not adequate to derive background values of chromium (VI). Preliminary remediation goals for chromium (III) and chromium (VI) are for "chromium" in Energy Systems 1996a.

[e] Cyanide is not expected to be naturally occurring in soil at PGDP; background values were not derived.

[f] Data are not adequate to calculate a background concentration in soil for this analyte.

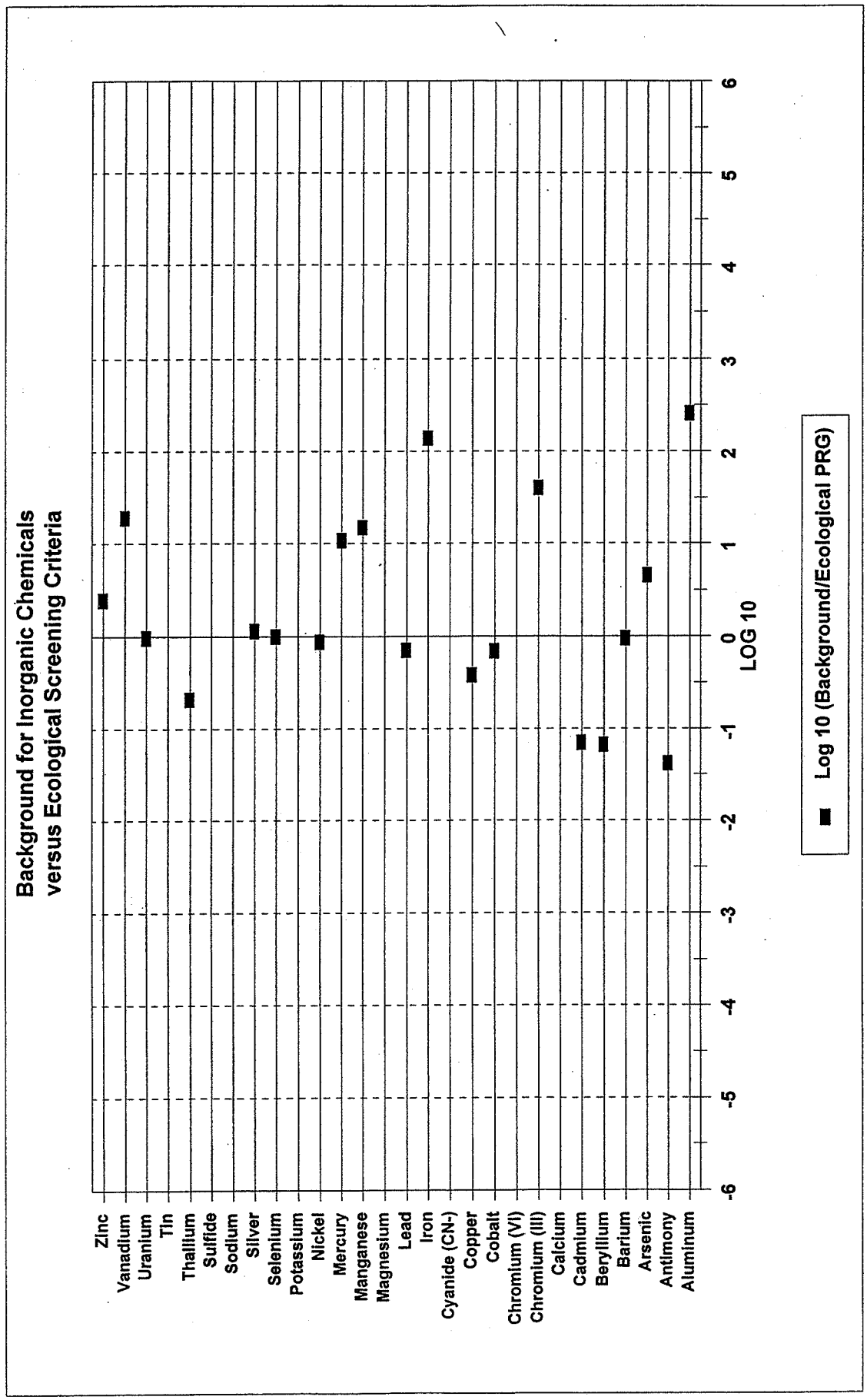


**Fig. 4.13. Comparison of background of inorganic chemicals in surface soil to ecological endpoint PRGs for soil.**

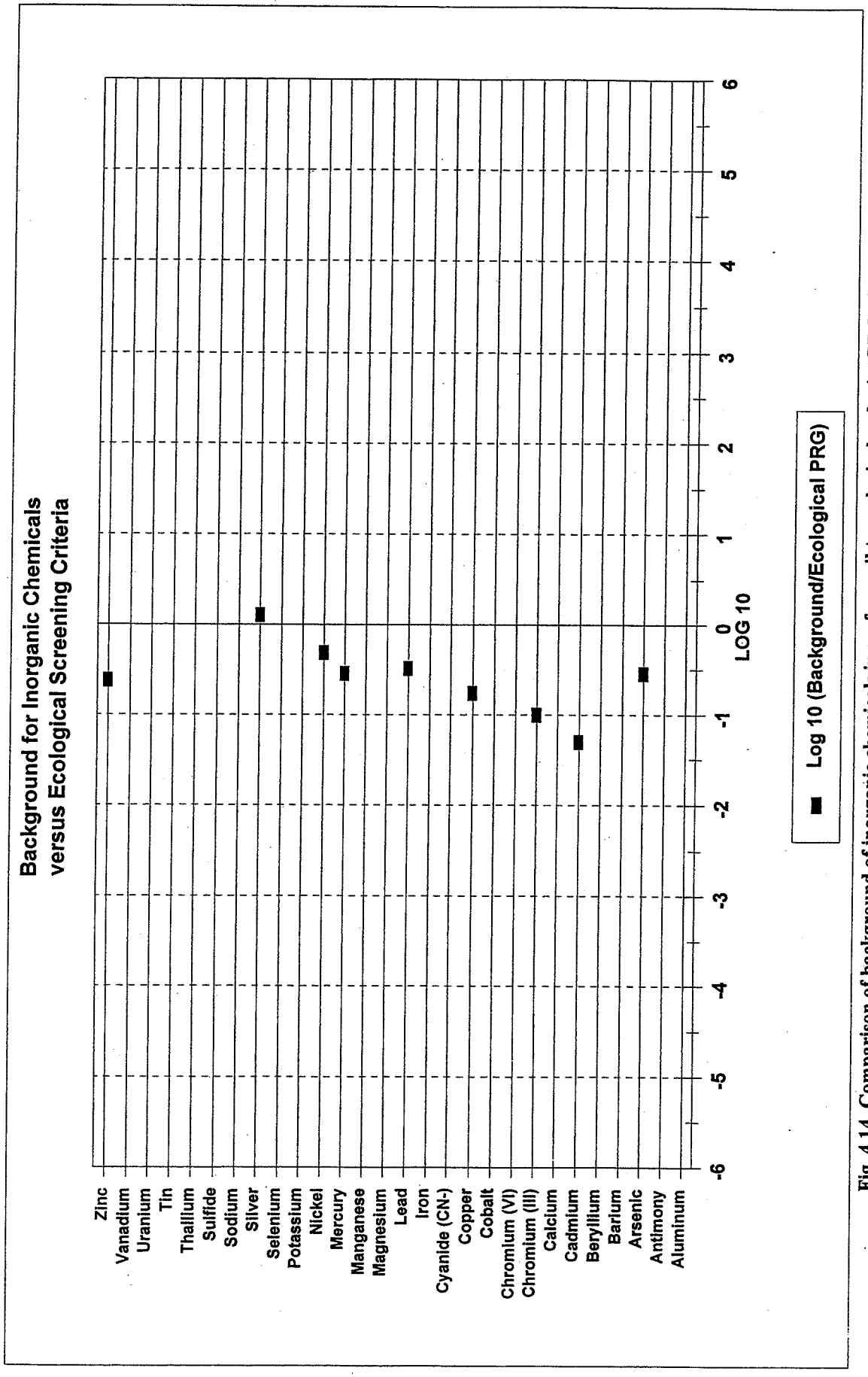


Fig. 4.14. Comparison of background of inorganic chemicals in surface soil to ecological endpoint PRGs for sediment.

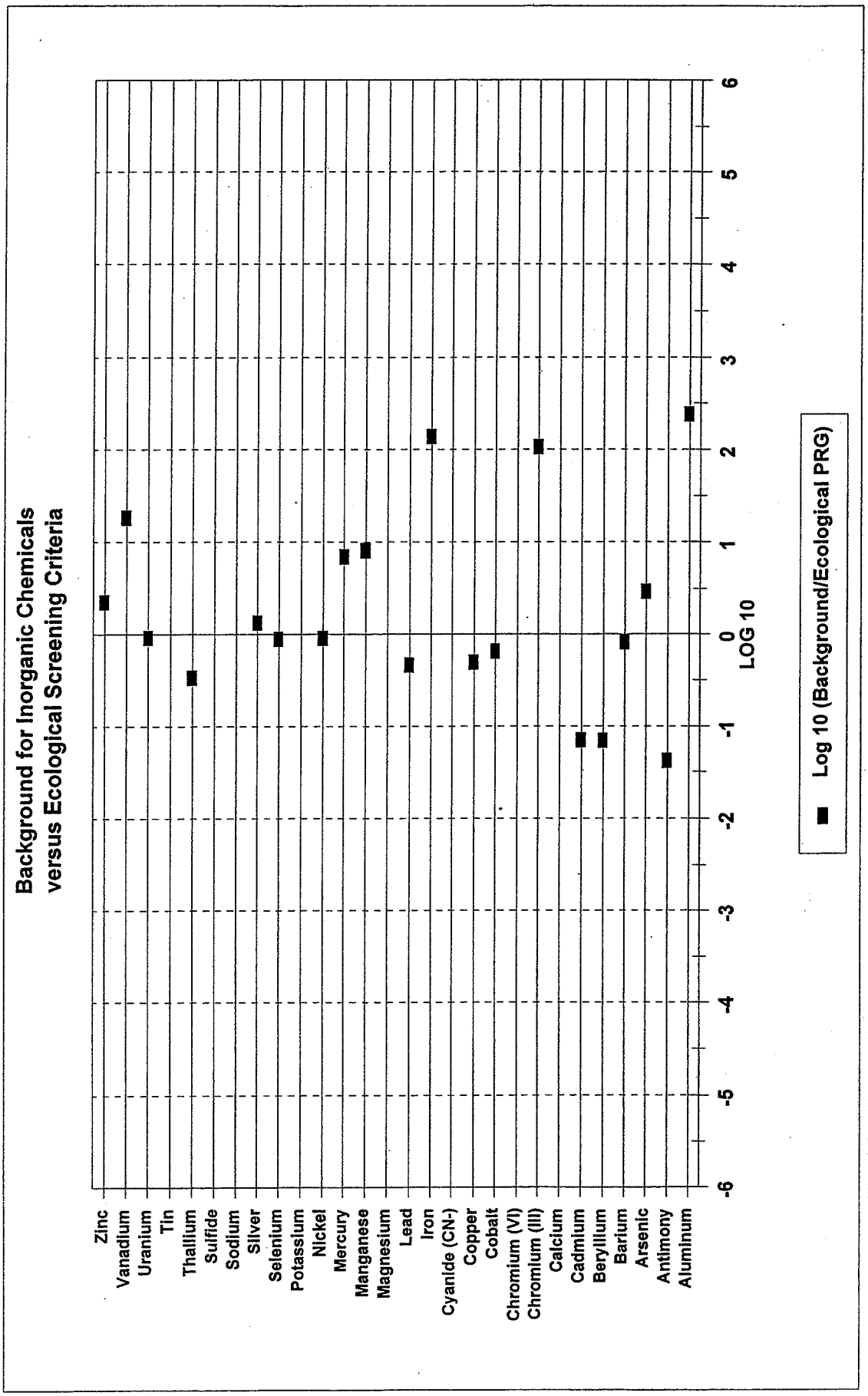


Fig. 4.15. Comparison of background of inorganic chemicals in subsurface soil to ecological endpoint PRGs for soil.

investigation process outlined in Appendix VII of the draft *Site Management Plan, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1996e). Specific portions of the investigation process in which background concentrations will be used for screening are further discussed in DOE 1996c. These portions are as follows:

- risk evaluations performed during the preliminary assessment/site evaluation to determine if further site characterization is required;
- risk evaluations used to prioritize further site characterization;
- risk evaluations used to determine the media to be sampled during a remedial investigation (e.g., work plan preparation), including the number of samples per medium, the number of samples per sampling location, and the analyte list for laboratory analysis;
- risk evaluations performed to determine if further sampling is required to characterize a site during phased remedial investigations; and
- baseline risk assessments to determine if the concentrations of contaminants at a site pose unacceptable risk or hazard to human health and the environment at a site or at locations away from the site.

In each of the aforementioned list items, the maximum detected concentrations of detected analytes will be directly compared to the background concentrations. If the maximum detected concentration of an analyte is found to be less than that contaminant's background concentration (and sampling is deemed adequate), then the analyte will be assumed to be detected at a naturally occurring concentration. Analytes assumed to be present at naturally occurring concentrations may then be removed from further consideration as site contaminants in the risk evaluation or assessment.

Removing analytes from risk evaluations or assessments on the basis of background comparisons may have a significant impact on the results of the risk evaluation or assessment. For example, as discussed in Subsect. 4.2, the background concentration of several analytes significantly exceeds the analyte's risk-based or hazard-based PRG. This indicates that the risk or hazard posed by the analyte at its natural concentration at PGDP may make up a substantial portion of the natural risks and hazards at PGDP. Therefore, total risk or hazard determined in a risk assessment in which risks or hazard are calculated including analytes detected at or less than their background concentrations would be much greater than in a risk assessment in which these analytes are not included.

The importance of this phenomenon and ways to address it are discussed at length in the draft final *Options for Addressing High Background Levels of Hazardous Substances at CERCLA Sites* (EPA 1992). In this document, it is noted that if inorganic chemicals are present at a site at naturally occurring levels that do not present significant risk, they may be eliminated from the quantitative risk assessment. However, it is emphasized that if these background concentrations appear to present a significant risk, then this risk should be calculated separately and this information should be noted in the risk assessment. (Note, the analysis presented in Subsect. 4.2 is meant to serve as this separate analysis of "background risks." Therefore, this analysis will not need to be performed in each risk assessment performed for PGDP.)

An important consideration is the selection of clean-up goals for analytes that occur naturally at concentrations that significantly exceed human health risk-based or hazard-based screening criteria or ecological risk-based screening criteria. In EPA 1992, two options are discussed

regarding the selection of clean-up levels for these types of analytes. These options are cleanup to background levels (Option 1) and cleaning up beyond background levels (Option 2). For PGDP, the analysis in Subsect. 4.2 shows that the analytes that significantly exceed human health risk-based or hazard-based screening criteria are Al, As, Be, Fe, Pb, Mn, V, $^{40}K$, and $^{226}Ra$. The analysis in Subsect. 4.2 also shows that the analytes that exceed ecological risk-based screening criteria are Al, As, Cr (III), Fe, Mn, Hg, Ag, V, and Zn. Therefore, at PGDP there are several analytes that occur at elevated naturally occurring concentrations that may deserve special attention when selecting clean-up goals.

When selecting clean-up goals for analytes with naturally occurring concentrations that significantly exceed risk-based or hazard-based screening criteria, it is important to remember that analyte speciation was ignored in the analyses presented in Subsect. 4.2. This is an important consideration because traditionally the studies used to develop toxicity values used in the calculation of the risk-based and hazard-based screening criteria are the most biologically available or toxic form of an analyte or both. Unfortunately, it is not known if the form of the analyte present in the environment at PGDP is the most biologically available or toxic form of the analyte or if it exists in some other form. Because of this uncertainty, the analyses in Subsect. 4.2 may be very conservative and overestimate the "background risks" presented by the analytes listed in the preceding paragraph. Therefore, analyte speciation should also be considered when selecting clean-up goals for those analytes that have background concentrations exceeding risk-based or hazard-based screening criteria.

# 5. SUMMARY AND CONCLUSIONS

The purpose of this study was to establish background levels of selected radionuclides and metals in soils near the PGDP. To do this, the activities and concentrations of selected radionuclides and metals were determined in soils and deep geologic media in the vicinity of the PGDP. The A and B horizons of three dominant soils series of the PGDP were sampled from a 6- by 12-mile area west-northwest of the PGDP. Deep geologic media were sampled from the dominant hydrologic units immediately south and west of to the PGDP. The selected radionuclides included $^{137}Cs$, $^{237}Np$, $^{238}Pu$, $^{226}Ra$, $^{90}Sr$, $^{99}Tc$, $^{228}Th$, $^{230}Th$, $^{232}Th$, $^{234}U$, $^{235}U$, $^{238}U$ and $^{40}K$. The selected metals included Sb, Be, Cd, Tl, and total U.

All of the project's stated objectives were accomplished. They included:

- determining background levels of selected radionuclides and metals in undisturbed soils providing a useable database for establishing clean-up levels of contaminants,
- developing a validated and defensible baseline database that could be used for contaminant assessment, and
- providing a database to evaluate risk from constituents in background soils for comparison with risk from contaminated sites.

The initial step involved establishing the background levels of selected radionuclides and metals in soils near the PGDP. Background levels of a particular analyte in soils comprise a population of measured values. The variability in values and range of such a population are dictated by a variety of factors, some being the mineralogical, physicochemical, and weathering of the soils as well as the error associated with measurement of the specific analyte. Many other factors too numerous to elucidate here also determine magnitude and variability in soil. The important point, in a pragmatic sense, is how one is to establish a level at which there is sufficient evidence that a measurement does not belong to the population of background values. Such levels are needed to determine if the soil is "contaminated" as well as to evaluate risks associated with concentrations of potential contaminants in soil that exceed background concentrations.

In Chapter 4, the background concentrations for measured analytes in this study were set at their 95% UTB on the 95$^{th}$ percentile concentration to remain consistent with the background threshold values selected by DOE (1996a). This statistical determination (the 95% confidence boundary for the 95 percentile estimate) was used to delineate the upper boundary between a normal background distribution that might occur in soils to that encountered in a contaminated environment. In this framework, the UTB has been defined as the background level for that analyte. From this viewpoint, any analyte whose level is above its UTB can be confidently considered above background. Therefore, for this report, the UTBs were defined as "background" levels.

Risk evaluations were conducted using the UTBs measured in the A and B soil horizons from the three dominant soil series near the PGDP (Tables 3.3 and 3.4). For the radionuclide data, this included the analyses of 15 (12 plus 3 field duplicates) composite soil samples for each horizon (each composite sample contained soil from three equivalent soil sites of the same soil series); therefore, these analyses represented 36 soil sampling sites. Similar statistics apply to the metals data (total uranium included) except for antimony and cadmium (where all samples collected were below the 0.021 mg/kg instrumental detection limit) and for thallium (where only 4 and 12 composite samples were above the detection limit) for the A and B horizons, respectively.

Background levels for the radionuclides and metals (as defined by the UTB) within the various soil horizons/hydrologic units are summarized in Tables 5.1 and 5.2, respectively.

For the radionuclides (excluding $^{40}K$), the respective values determined for the mean, lower tolerance bound (LTB), 95%-ile, and UTB in the A horizons of the three soils have been plotted in Fig. 5.1. For most radionuclides, there was little difference in estimates for UTB and the 95%-ile; the exceptions being $^{90}Sr$, $^{99}Tc$, and $^{234}U$. Note that estimates for UTB are much higher than the mean or 95%-ile for $^{90}Sr$, $^{99}Tc$, and $^{234}U$. The extreme example is $^{90}Sr$ where the UTB value was determined to be 4.71 pCi/g compared with 0.000 and 0.296 pCi/g for the mean and 95%-ile, respectively. The range in $^{90}Sr$ values was from -0.280 to 0.22 pCi/g (Table 3.3). The coefficient of variance [(standard error of the mean) divided by the mean] was >40 indicating a large variability which is reflected in the high UTB. Therefore, the use of the UTB for determining a background value for $^{90}Sr$ likely overestimates it. In instances where a high degree of variability is included in the data set, a better approach for determining background values might be the 95%-ile. From this stand point, it is important to consider the influence of variability in the data plus other factors when establishing "background" levels in soils and geologic media.

**Table 5.1. Background levels of radionuclides in soils and deep geologic media in the vicinity of the PGDP[a]**

| Soil horizon/ hydrologic unit | Cs-137 | K-40 | Np-237 | Pu-238 | Pu-239 | Ra-226 | Sr-90 | Tc-99 | Th-228 | Th-230 | Th-232 | U-234 | U-235 | U-238 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (pCi/g) | | | | | | | | | | | | | |
| A | 0.494 | 16.031 | 0.102 | 0.073 | 0.025 | 1.481 | 4.719 | 2.535 | 1.582 | 1.452 | 1.476 | 2.485 | 0.144 | 1.221 |
| B | 0.283 | 16.248 | nm[b] | nm | nm | 1.518 | nm | 2.779 | 1.586 | 1.445 | 1.487 | 2.438 | 0.143 | 1.166 |
| Loess | 0.139 | 13.036 | nm | nm | nm | 1.089 | nm | 0.496 | 1.180 | 1.217 | 1.225 | 1.040 | 0.128 | 0.921 |
| HU-2 | 0.140 | 6.431 | nm | nm | nm | 1.050 | nm | 0.496 | 1.061 | 0.882 | 1.078 | 0.953 | 0.117 | 0.977 |
| HU-3 | 0.143 | 5.256 | nm | nm | nm | 1.150 | nm | 0.548 | 1.396 | 1.053 | 1.326 | 1.182 | 0.112 | 1.009 |
| Eoc. Sand | 0.147 | 2.451 | nm | nm | nm | 0.570 | nm | 0.521 | 0.541 | 0.374 | 0.577 | 0.492 | 0.092 | 0.401 |
| PC Clay | 0.141 | 9.501 | nm | nm | nm | 1.213 | nm | 0.634 | 1.393 | 1.153 | 1.422 | 1.429 | 0.167 | 1.288 |

Notes:
[a]Background levels are defined as the upper tolerance bound of the 95 percentile.
[b]Not measured in subsurface horizons.



**Table 5.2. Background levels of metals in soils and deep geologic media in the vicinity of the PGDP[a]**

| Soil horizon/ hydrologic unit | Beryllium | Thallium | Total uranium |
|---|---|---|---|
| | (mg/kg) | | |
| A | 0.673 | 0.209 | 4.853 |
| B | 0.686 | 0.336 | 4.637 |
| Loess | 0.604 | 0.216 | 3.663 |
| HU-2 | 0.504 | bd[b] | 3.883 |
| HU-3 | 0.747 | 0.255 | 4.012 |
| Eoc. Sand | bd | bd | 1.595 |
| PC Clay | 1.282 | 0.542 | 5.122 |

Notes:
[a]Background levels are defined as the upper tolerance bound of the 95 percentile. For risk analyses, the background level from A horizon is to be used for surface soil (i.e., 0 to 1 ft below ground surface), and the background level from B horizon is to be used for subsurface soil (i.e., more than 1 ft below ground surface). In addition, in risk analyses, the maximum detection limit used for antimony and cadmium analyses (0.21 mg/kg) should be used as the background level of these analytes in both surface and subsurface soil.
[b]Below detection.

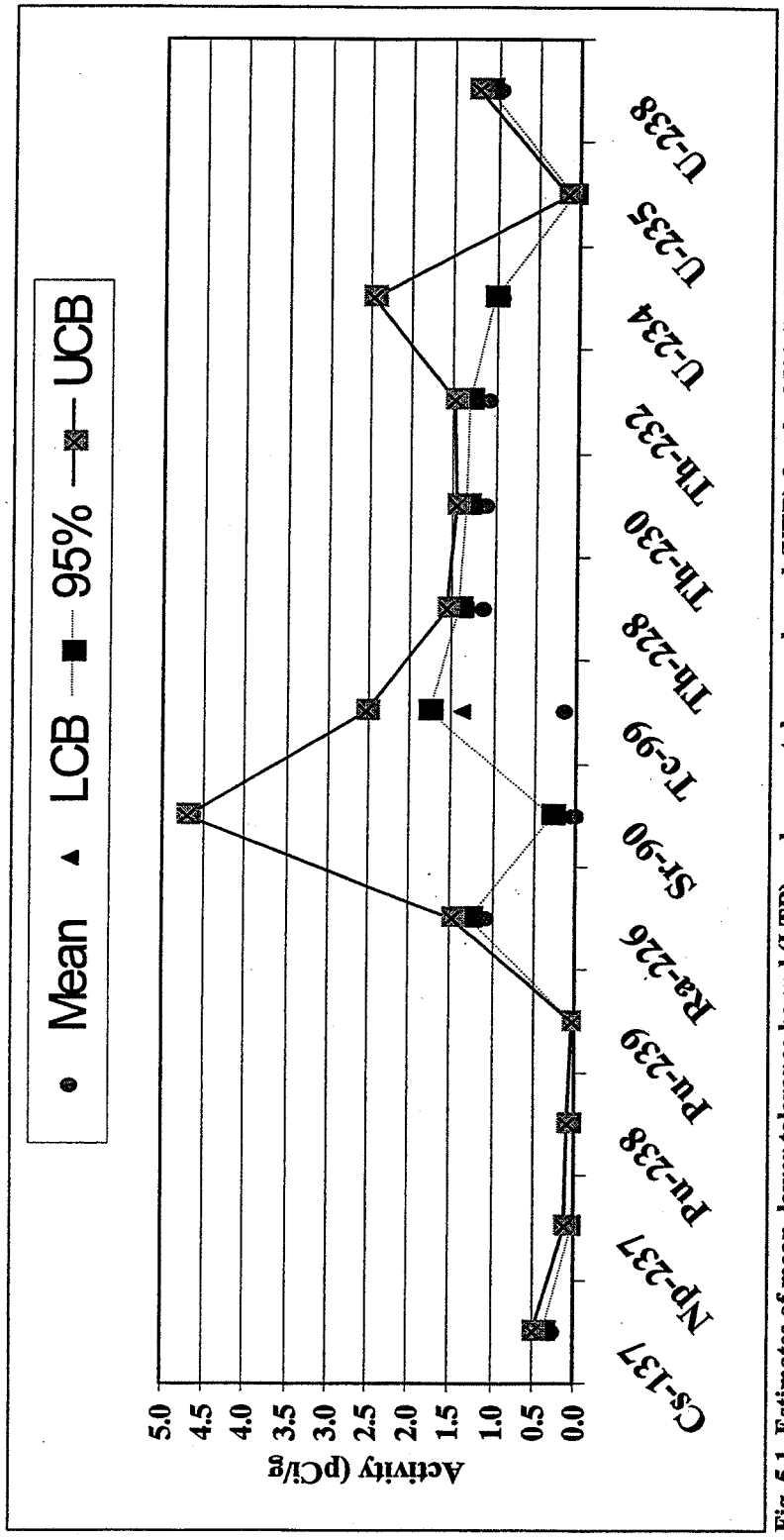


**Fig. 5.1. Estimates of mean, lower tolerance bound (LTB) and upper tolerance bound (UTB) for the 95%-ile for radionuclides in the A horizon of the three dominant soil series in the vicinity of the PGDP.**

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# APPENDIX A

# SOIL SAMPLE SITES AND SOIL PROFILE DESCRIPTIONS

## Location of Soil Sampling Sites and Description of Soil Profiles

Soils were collected from the A and B horizons at 36 soil sites. These sites (12 from each of the three soil series) were selected after careful examination of the soil profiles ensuring that each site met the criteria established for its respective soil mapping unit. Locations of these sites are illustrated on Fig. A.1. Site locations prefixed with the letter "C" are representative of soils from the Calloway-Gernada soil series; those with "F," the Falaya-Collins-Waverly series; and those with "H," the Henry series. The listing of the latitude and longitude locations of these sites are available in Table A.1. Composite samples were generated by collecting samples from three of these sites. Sample sites and sample descriptions making up these composites are described in Appendix C.

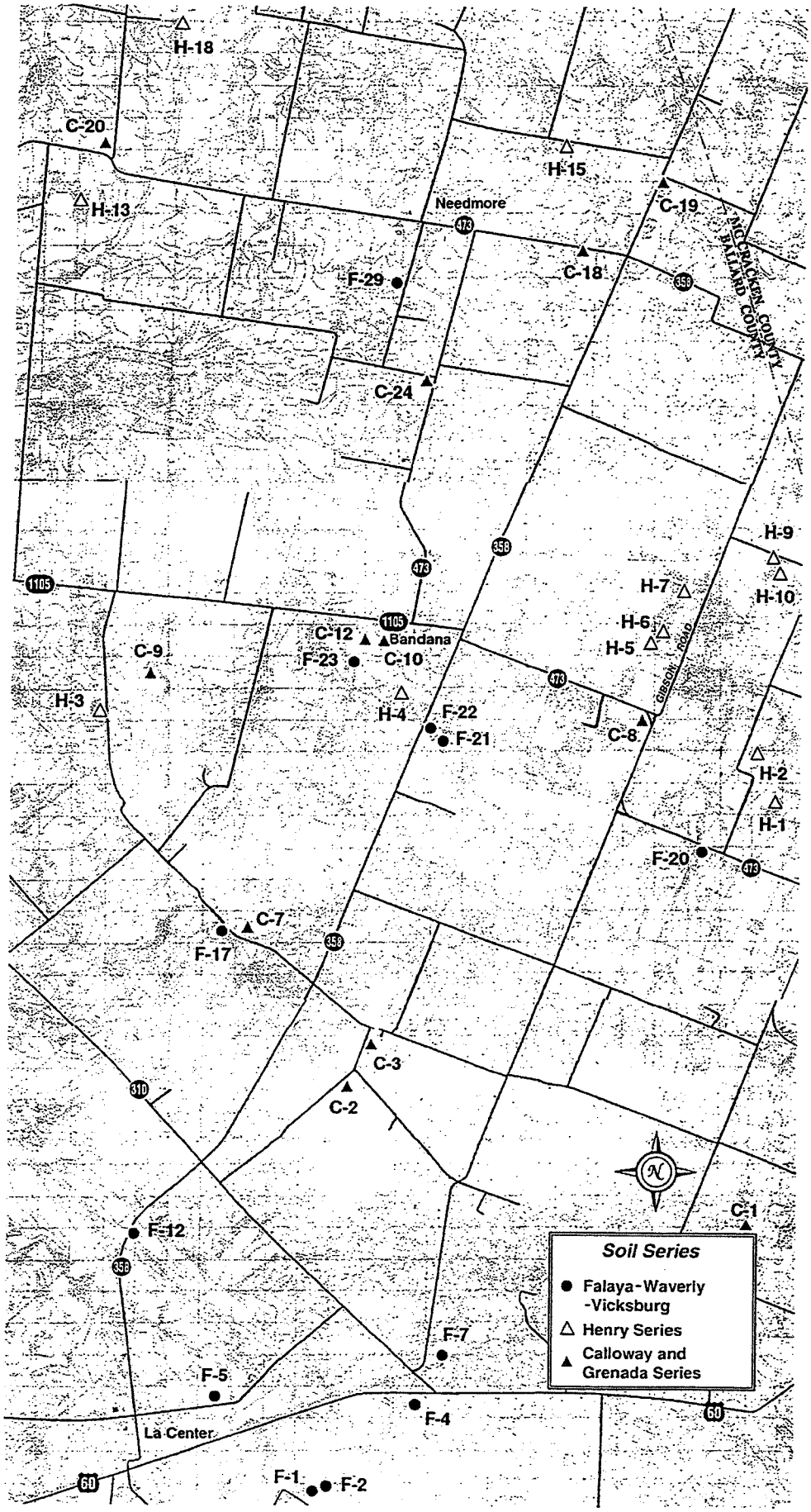


**Fig. A.1. Soil sample sites in Ballard and McCracken counties.**

**Table A.1. Locations of surface soil sampling sites**

| Sample Site | Latitude | Longitude |
|---|---|---|
| C-1 | 88°54'36" | 37°05'35" |
| C-2 | 88°57'07" | 37°06'20" |
| C-3 | 88°56'57" | 37°06'35" |
| C-7 | 88°57'45" | 37°07'10" |
| C-8 | 88°55'15" | 37°08'17" |
| C-9 | 88°58'24" | 37°08'29" |
| C-10 | 88°56'57" | 37°08'43" |
| C-12 | 88°57'03" | 37°08'45" |
| C-18 | 88°55'54.5" | 37°10'42.5" |
| C-19 | 88°55'18" | 37°11'06" |
| C-20 | 88°58'47" | 37°11'12.5" |
| C-24 | 88°56'45" | 37°10'02" |
| F-1 | 88°57'15" | 37°04'15" |
| F-2 | 88°57'09" | 37°04'15" |
| F-4 | 88°56'36" | 37°04'43" |
| F-5 | 88°57'54" | 37°04'45" |
| F-7 | 88°56'30" | 37°04'57.5" |
| F-12 | 88°58'26.5" | 37°05'35" |
| F-17 | 88°57'57" | 37°07'09" |
| F-20 | 88°54'54" | 37°07'37" |
| F-21 | 88°56'33" | 37°08'10" |
| F-22 | 88°56'39" | 37°08'12" |
| F-23 | 88°57'07" | 37°08'32" |
| F-29 | 88°56'58" | 37°10'32.5" |

**Table A.1. (continued)**

| Sample Site | Latitude | Longitude |
|---|---|---|
| H-1 | 88°54'24" | 37°07'51" |
| H-2 | 88°54'31" | 37°08'08" |
| H-3 | 88°58'44" | 37°08'15" |
| H-4 | 88°56'49" | 37°08'24" |
| H-5 | 88°55'14" | 37°08'42.5" |
| H-6 | 88°55'11" | 37°08'47.5" |
| H-7 | 88°55'04" | 37°08'57.5" |
| H-9 | 88°54'27" | 37°09'08" |
| H-10 | 88°54'26" | 37°09'03" |
| H-13 | 88°58'57" | 37°10'52" |
| H-15 | 88°55'54" | 37°11'15" |
| H-18 | 88°58'21" | 37°11'45" |

## Soil Sample Site Descriptions

**Site No. C-1**

Map Unit Delineation: Grenada.
Soil Classified as: Aquic Hapludalfs; or Aquultic Hapludalfs; fine-silty, mixed, thermic.
Soil Series Identified as: Loring, non-fragipan Variant.

Location: Ballard County, Kentucky, North off of Clarkline Road
Geomorphic Position: High terrace or broad undissected upland.
Slope and Aspect: 2-5%.
Parent Material(s): Loess or alluvium from loess.
Vegetation: Wheat in 95 and soybeans in 96.
Erosion: Estimated to be minimal.
Described By: Lietzke
Date: 7-16-96

Soil Description
Ap 0 to 20 cm; brown (10YR 4/3) silt loam.
BE 20 to 65 cm; yellowish brown (10YR 5/6) silt loam.
Bt 65 to 95 cm; brown (10YR 5/3) silty clay loam with yellowish brown Fe accumulations; soft Mn concentrations; white (10YR 8/1) skeletans on prism faces; light gray (10YR 6/1) in water flow zones.
C 95 to 110 cm; strong brown (7.5YR 4/6) silt loam; brown (10YR 4/3 and 10YR 5/3) depleted areas; light gray (10YR 7/1) in flow zones; few to common soft Mn accumulations.

**Site No. C-2**

Map Unit Delineation: Grenada, B slopes.
Soil Classified as: Typic or Aquic Hapludalfs; fine-silty, mixed, thermic.
Soil Series Identified as: Loring-Grenada Intergrade, non-pan Variant.

Location: Ballard County, Kentucky. Jones Roads, south off of Clarkline Road then east into field.
Geomorphic Position: Elongated narrow ridge on broad loess covered terrace.
Slope and Aspect: 2-5%.
Parent Material(s): Loess or alluvium from loess.
Vegetation: Wheat in 95and hayfield in 96.
Erosion: Estimated to be light to moderate.
Described By: Lietzke
Date: 7-16-96

Soil Description
Ap 0 to 20 cm; dark yellowish brown (10YR 4/4) silt loam.
BE 20 to 25 cm; yellowish brown (10YR 5/4) silt loam.
Bt1 25 to 50 cm; yellowish brown (10YR 5/4) silty clay loam with surficial light gray (10YR 7/2) siltans on flow zone surfaces.
Bt2 50 to 80 cm; brown (10YR 5/3) silty clay loam with yellowish brown (10YR 5/6) Fe accumulations; numerous soft black Mn accumulations; light gray (10YR 7/2) flow zones.
C 80 to 110 cm; yellowish brown (10YR 5/6) silt loam; grayish brown (10YR 5/2) flow zones; strong brown (7.5YR 4/6) Fe accumulations; very few Mn accumulations.

**Site No. C-3**

Map Unit Delineation: Grenada, B slopes.
Soil Classified as: Aquic Hapludalfs or Glossaquic Hapludalfs; fine-silty, mixed, thermic.
Soil Series Identified as: Center.

Location: Ballard County, Kentucky. On Jones Road, south of intersection of Mt. Pleasant Church Road then 120 feet into field.
Geomorphic Position: Higher area of broad upland or loess covered terrace.
Slope and Aspect: 2-5%.
Parent Material(s): Loess or alluvium from loess.
Vegetation: Wheat in 95 and soybeans in 96.
Erosion: Estimated to be slight.
Described By: Lietzke.
Date: 7-16-96

Soil Description
Ap 0 to 20 cm; brown (10YR 4/3) silt loam.
BE 20 to 40 cm; yellowish brown (10YR 5/4) silt loam; common to many black Mn nodules 1-2 mm in diameter.
Bt 40 to 90 cm; grayish brown (10YR 5/2) and brown (10YR 5/3) silty clay loam; yellowish brown (10YR 5/6) Fe accumulations; black Mn nodules 2-5 mm in diameter.
C 90 to 110 cm; light brownish gray (2.5Y 6/2) and dark yellowish brown (10YR 4/4) silt loam; light gray (10YR 7/1) siltans on flow surfaces.

**Site No. C-7**

Map Unit Delineation: Grenada.
Soil Classified as: Glossic or Glossaquic Hapludalfs or Glossudalfs; fine-silty, mixed, thermic.
Soil Series Identified as: Center.

Location: Ballard County, Kentucky. Kirkman Road and 130 feet north into corn field.
Geomorphic Position: Upland bench below a higher area of Loring and above a Calloway area.
Slope and Aspect: 2-5%.
Parent Material(s): Loess.
Vegetation: Continuous corn, 95 and 96.
Erosion: Moderately eroded.
Described By: Lietzke
Date: 7-10-96

Soil Description
Ap 0 to 25 cm; dark yellowish brown (10YR 4/4) silt loam.
E 25 to 35 cm; light yellowish brown (10YR 6/4) silt loam.
E&B 35 to 45 cm; light gray (10YR 7/2) silt loam E part and light yellowish brown (2.5Y 6/3) silty clay loam B part.
Bt1 45 to 55 cm; light olive brown (2.5Y 5/3) and light brownish gray (2.5Y 6/2) silty clay loam; yellowish brown (10YR 5/6) Fe accumulations and soft Mn accumulations; strong prismatic structure.
Btg1 55 to 80 cm; light brownish gray (2.5Y 6/2) silty clay loam; yellowish brown (10YR 5/6) Fe concentrates; very dark grayish brown (10YR 3/2) Mn nodules 5 to 10 mm in size.
Btg2 80 to 90 cm; light brownish gray (10YR 6/2) and pale brown (10YR 6/3) silty clay loam; yellowish brown (10YR 5/6) Fe concentrates and Mn nodules.
C1 90 to 110; brown (10YR 5/3) silt loam or silty clay loam; light brownish gray (10YR 6/2) flow zones and splotches.
C2 110 to 120 cm; light brownish gray (10YR 6/2) and brown (10YR 5/3) silt loam; diffuse Fe and Mn accumulations.

**Site No. C-8**

Map Unit Delineation: Calloway
Soil Classified as: Aeric Epiaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Kurk

Location: Ballard County, Kentucky. Intersection of Rt. 473 and Gibson Road then 100 feet west into field.
Geomorphic Position: Broad terrace
Slope and Aspect: 0-2%.
Parent Material(s): Loess and alluvium from loess.
Vegetation: Wheat in 95 and soybeans in 96.
Erosion: Slight.
Described By: Lietzke.
Date: 7-11-96

Soil Description
Ap 0 to 28 cm; brown (10YR 4/3) silt loam; few 1-2 mm Mn nodules.
E 28 to 45 cm; light brownish gray (10YR 6/2) silt or silt loam; many small hard Mn nodules 1 mm in diameter; few dark yellowish brown (10YR 4/6) Fe accumulations.
Btg 45 to 90 cm; brown (10YR 5/3) and light brownish gray (10YR 6/2) matrix; silty clay loam; light brownish gray (10YR 6/2) depletions in flow zones; strong brown (7.5YR 4/6) Fe accumulations.
Bt 90 to 120 cm; brown (10YR 5/3-4/3) silty clay loam; dark yellowish brown (10YR 4/6) Fe accumulations; common light brownish gray (10YR 6/2) flow zones; light gray (10YR 7/1) siltans in flow zones.

**SITE No.C-9**

Map Unit Delineation: Grenada
Soil Classified as: Aquic Hapludalfs; fine-silty, mixed, thermic.
Soil Series Identified as: Center

Location: Ballard County, Kentucky. Driveway off of Kirkland Rd and then 75 feet south into field.
Geomorphic Position: High area on broad terrace or upland.
Slope and Aspect: 2-5%.
Parent Material(s): Loess or alluvium from loess.
Vegetation: Hayfield.
Erosion: Slight.
Described By: Elless
Date: 7-15-96

Soil Description
Ap 0 to 20 cm; brown (10YR 4/3) silt loam.
Bt1 20 to 30 cm; yellowish brown (10YR 5/6) silty clay loam; few brown (10YR 5/3) depletions.
Bt2 30 to 60 cm; brown (10YR 5/3) silty clay loam; light brownish gray (10YR 6/2) depletions in flow zones; strong brown (7.5YR 5/8) Fe accumulations.
Bt3 60 to 90 cm; brown (10YR 5/3) silty clay loam; light brownish gray (10YR 6/2) depletions in flow zones; strong brown (7.5YR 5/8) Fe accumulations; few Mn stains.
BC 90 to 120 cm; brown (10YR 5/3) to yellowish brown (10YR 5/4) silty clay loam; Light brownish gray (10YR 6/2) depletions in flow zones; strong brown (7.5YR 5/8) Fe accumulations; Mn staining.

**SITE No. C-10**

Map Unit Delineation: Grenada
Soil Classified as: Aquic or Glossaquic Hapludalfs; fine-silty, mixed, thermic.
Soil Series Identified as: Center

Location: Ballard County, Kentucky. South and east of Bandana Methodist Church.
Geomorphic Position: Terrace
Slope and Aspect: 2-5%
Parent Material(s): loess and alluvium from loess.
Vegetation: Corn 95, wheat 95, and Soybeans 96
Erosion: Slight
Described By: Lietzke
Date: 7-9-96

Soil Description
Ap 0 to 20 cm; dark brown (10YR 3/3) silt loam.
Bt 20 to 40 cm; light yellowish brown (2.5Y 6/3) silt loam; light gray (10YR 7/1) flow zone streaks.
2E&B 40 to 60 cm; white (10YR 8/1) silt or silt loam E part as tonguing and coatings on prism faces and light yellowish brown silty clay loam B part; yellowish brown (10YR 5/6) Fe accumulations in B part; Mn is depleted.
2Bt 60 to 100 cm; yellowish brown (10YR 5/6) silty clay loam; light gray (10YR 7/1) flow zones; few black Mn nodules; splotches of brown (10YR 5/3).

**SITE No. C-12**

Map Unit Delineation: Calloway
Soil Classified as: Aeric Epiaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Kurk

Location: Ballard County, Kentucky. 580I due south of Bandana Methodist Church.
Geomorphic Position: Terrace.
Slope and Aspect: 0-2%
Parent Material(s): Loess and alluvium from loess.
Vegetation: Corn 95, wheat 95, and soybeans 96.
Erosion: Slight.
Described By: Lietzke
Date: 7-9-96

Soil Description
Ap 0 to 25 cm; dark yellowish brown (10YR 4/4) silt loam.
BE 25 to 40 cm; light brownish gray (2.5Y 6/2) and light yellowish brown (2.5Y 6/3) silt loam; dark yellowish brown (10YR 4/4) Fe nodules; very dark grayish brown(10YR 3/2) Mn concentrations 1-2 mm in diameter.
Bt 40 to 52 cm; light olive brown (2.5Y 5/3) silt loam; many light brownish gray (2.5Y 6/2) depletions and flow zones.
Btg 52 to 100 cm; light brownish gray light silty clay loam; yellowish brown (10YR 5/6) Fe accumulations; very dark grayish brown (10YR 3/2) Mn nodules.
2Bt 100 to 120 cm; light olive brown (2.5Y 5/3) silty clay loam; dark yellowish brown (10YR 4/6) and yellowish brown (10YR 5/6) Fe accumulations.

**SITE No.C-18**

Map Unit Delineation: Calloway
Soil Classified as: Aeric Glossaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Kurk

Location: Ballard County, Kentucky. East of Route 473-1782 intersection on Rt 1782 then 100 feet south into field.
Geomorphic Position: Edge of nearly level broad upland or terrace.
Slope and Aspect: 0-2%.
Parent Material(s): Loess and alluvium from loess.
Vegetation: Wheat 95 and soybeans 96.
Erosion: Moderate.
Described By: Lietzke.
Date: 7-16-96.

Soil Description
Ap 0 to 13 cm; brown (10YR 4/3) silt loam; few hard Mn nodules 1-2 mm in diameter.
E 13 to 25 cm; brown (10YR 5/3) silt loam; many Mn nodules; yellowish brown (10YR 5/6) Fe accumulations.
Btg 25 to 73 cm; grayish brown (10YR 5/2) silty clay loam; yellowish brown (10YR 5/6) Fe accumulations; common hard Mn nodules with an Fe oxide rind.
Bt 73 to 110 cm; brown (10YR 5/3) silty clay loam; yellowish brown (10YR 5/6-5/8) Fe accumulations; many large Mn nodules surrounded by a Fe oxide rind; light gray (10YR 7/1) depletions in flow zones.

**SITE No. C-19**

Map Unit Delineation: Calloway.
Soil Classified as: Aeric Epiaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Kurk

Location: Ballard County, Kentucky. 100 feet south of Bandana Road and Ogden Landing Road intersection and 100 feet east into field.
Geomorphic Position: Terrace close to Ohio River terraces.
Slope and Aspect: 0-2%.
Parent Material(s): Loess over alluvium from loess.
Vegetation: Scattered trees, cleared about 25 years ago. Present land use is fescue hay field.
Erosion: Slight.
Described By: Lietzke.
Date: 7-17-96

Soil Description
Ap 0 to 20 cm; dark yellowish brown (10YR 4/4) silt loam.
BE 20 to 40 cm; brown (10YR 5/3) silt loam; yellowish brown (10YR 5/6) Fe accumulations; light gray (10YR 7/1) depleted flow zones.
Btg 40 to 70 cm; grayish brown (10YR 5/2) silty clay loam; yellowish brown (10YR 5/6) Fe accumulations; few hard Mn nodules; strong brown (7.5YR 5/8) coatings on ped faces; light gray (10YR 7/1) depleted flow zones.
Bt 70 to 110 cm; brown (10YR 5/3) silty clay loam; splotches and coatings of yellowish brown (10YR 5/6); light gray (10YR 7/1) siltans in flow zones.

**SITE No. C-20**

Map Unit Delineation: Calloway.
Soil Classified as: Aeric Epiaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Kurk.

Location: Ballard County, Kentucky. 200 feet northwest of Monkey Eyebrow Road and Ogden-Colvin Road intersection in a soybean field.
Geomorphic Position: Broad terrace.
Slope and Aspect: 0-2%.
Parent Material(s): Loess and alluvium from loess.
Vegetation: Soybeans 95.
Erosion: Slight.
Described By: Lietzke.
Date: 7-17-96

Soil Description
Ap 0 to 17 cm; brown (10YR 4/3) silt loam; common to many hard Mn nodules.
E 17 to 50 cm; yellowish brown (10YR 5/4) silt loam; strong brown (7.5YR 5/8) Fe accumulations and grayish brown (10YR 5/2) depleted areas.
Eg&Btg 50 to 70 cm; light brownish gray (10YR 6/2) silt loam or silt E part and grayish brown (10YR 5/2) silty clay loam B part; large Mn nodules 2-8 cm in diameter; strong brown (7.5YR 5/6) Fe accumulations.
Btg 70 to 95 cm; grayish brown (10YR 5/2) silty clay loam; strong brown (7.5YR 5/6) Fe accumulations; many Mn nodules 5-8 mm in diameter; light gray (10YR 7/1 siltans in flow zones.
Bt 95 to 110 cm; brown (10YR 5/3) and yellowish brown (10YR 5/6) silty clay loam; many 2-5 mm diameter Mn nodules; light gray (10YR 7/1) depletions in flow zones.

**SITE No. C-24**

Map Unit Delineation: Calloway.
Soil Classified as: Aeric Epiaqualfs or Aeric Glossaqualfs; fine-silty. mixed, thermic.
Soil Series Identified as: Kurk.

Location: Ballard County, Kentucky. Intersection of Bill Holt Road and Route 473, then 100 feet south into field.
Geomorphic Position: Broad terrace or upland.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess and alluvium from loess.
Vegetation: Wheat 95 and soybeans 96.
Erosion: Slight.
Described By: Lietzke.
Date: 7-16-96

Soil Description
Ap 0 to 20 cm; brown (10YR 5/3-4/3) silt loam; few hard Mn nodules.
E 20 to 40 cm; brown (10YR 5/3) silt loam; light gray (10YR 7/1) depletions; few yellowish brown (10YR 5/6) Fe accumulations.
Btg 40 to 65 cm; grayish brown (10YR 5/2) silty clay loam; yellowish brown (10YR 5/6) Fe accumulations; few soft Mn nodules at 60 cm.
Bt 65 to 120 cm; brown (10YR 5/3) silty clay loam; yellowish brown (10YR 5/6) Fe accumulations; few light brownish gray (10YR 6/2) flow zone streaks.

**SITE No.F-1**

Map Unit Delineation: Falaya-Collins Complex or edge of Rosebloom.
Soil Classified as: Aeric Fluvaquents; coarse-silty, mixed, thermic.
Soil Series Identified as: Falaya

Location: Ballard County, Kentucky. On Route 358 south of LaCenter, then 420 feet along east edge of woods then 60 feet into cornfield.
Geomorphic Position: Broad alluvial floodplain.
Slope and Aspect: 0 to 2%.
Parent Material(s): Alluvium from loess.
Vegetation: Continuous corn.
Erosion: No evidence of any scouring or deposition.
Described By: Lietzke.
Date: 7-18-96

Soil Description
Ap 0 to 25 cm; brown (10YR 4/3) silt loam. many small hard Mn nodules.
Bw 25 to 40 cm; brown (10YR 5/3) and grayish brown (10YR 5/2) 50:50; silt loam; red coatings of Fe and streaks of yellowish brown (10YR 5/6) and strong brown (7.5YR 4/6); common hard small Mn nodules.
Cg 40 to 110 cm; light brownish gray (10YR 6/2) silt loam; many hard black Mn nodules having a strong brown (7.5YR 4/6) rind. Nodules and rinds are 3-8 mm in size; dark yellowish brown (10YR 4/6) Fe accumulations and coatings on crack surfaces; light gray clay filled krotovina between 90 and 110 cm.

**SITE No. F-2**

Map Unit Delineation: Boundary area between Rosebloom and Falaya-Collins delineations.
Soil Classified as: Aquic Udifluvents; coarse-silty, mixed. thermic.
Soil Series Identified as: Collins.

Location: Ballard County, Kentucky. On Route 358 south of LaCenter to corn field, then 850 feet north along east side of field then 130 feet west into cornfield.
Geomorphic Position: Broad alluvial bottom.
Slope and Aspect: 0 to 2%.
Parent Material(s): Alluvium from loess.
Vegetation: Continuous corn.
Erosion: No evidence of any scouring or deposition.
Described By: Lietzke.
Date: 7-18-96

Soil Description
Ap 0 to 25 cm; brown (10YR 4/3) silt loam.
Bw 25 to 45 cm; brown (10YR 5/3) silt loam; soft 1-2 mm Mn nodules; yellowish brown (10YR 5/6) Fe accumulations and threads.
C 45 to 110 cm; brown (10YR 5/3) and light brownish gray (10YR 6/2) silt loam; soft 1-2 mm Mn nodules; few yellowish brown (10YR 5/4) Fe oxidized splotches.

**SITE No. F-4**

Map Unit Delineation: Falaya-Collins complex.
Soil Classified as: Aquic Udifluvents; coarse-silty, mixed, thermic.
Soil Series Identified as: Collins

Location: Ballard County, Kentucky. Route 60 east of LaCenter and intersection of angled road, 100 feet through gate into pasture field.
Geomorphic Position: Broad alluvial floodplain.
Slope and Aspect: 0 to 2%.
Parent Material(s): Alluvium form loess.
Vegetation: Pasture.
Erosion: No evidence of any recent scouring or deposition.
Described By: Lietzke
Date: 7-9-96

Soil Description
Ap 0 to 25 cm; brown (10YR 4/3) silt loam; compacted from cattle traffic.
Bw1 25 to 55 cm; brown (10YR 4/3) silt loam; soft very dark grayish brown (10YR 3/2) Mn concentrations; grayish brown (10YR 5/2) depletions.
Bw2 55 to 90 cm; brown (10YR 5/3) silt loam; light brownish gray (10YR 6/2) depletions; brown (10YR 4/3) Mn accumulations; few hard Mn nodules 2-5 mm in size.
Cg 90 to 130 cm; light brownish gray (10YR 6/2) and brown (10YR 5/3) silt or silt loam; common hard Mn nodules.

**SITE No. F-5**

Map Unit Delineation: Falaya-Collins Complex.
Soil Classified as: Aeric Fluvaquents; coarse-silty, mixed, thermic.
Soil Series Identified as: Falaya.

Location: Ballard County, Kentucky. In LaCenter at the end of 4th Street then 200 feet north into soybean field.
Geomorphic Position: Broad alluvial floodplain.
Slope and Aspect: 0 to 2%.
Parent Material(s): Alluvium from loess.
Vegetation: Corn 95 and soybeans 96.
Erosion: No evidence of any recent scouring or deposition.
Described By: Lietzke
Date: 7-10-96

Soil Description
Ap 0 to 25 cm; brown (10YR 4/3) silt loam.
Bw 25 to 40 cm; brown (10YR 4/3) and dark grayish brown (10YR 4/2) silt loam; black Mn coatings on faces of cracks; few yellowish brown (10YR 5/60 Fe coatings; becoming dark grayish brown (2.5Y 4/2) at the lower part; few to common 2.5 mm Mn nodules.
Cg1 40 to 60 cm; grayish brown (10YR 5/2) silt loam; many black Mn coatings, accumulations and Mn nodules from 40 to 50 cm; few yellowish brown (10YR 5/6) Fe accumulations.
Cg2 60 to 105 cm; grayish brown (10YR 5/2) and light brownish gray (10YR 6/2) silt loam; fewer Mn accumulations; yellowish brown (10YR 5/6) splotches of fe accumulations.
2Cg3 105 to 115 cm; light brownish gray (2.5Y 6/2) silty clay loam; well defined strong brown (7.5YR 5/8) Fe accumulations in splotches; common to many 1-2 mm fairly hard Mn nodules.

**SITE No. F-7**

Map Unit Delineation: Waverly
Soil Classified as: Typic Fluvaquents; coarse-silty, mixed, thermic.
Soil Series Identified as: Waverly

Location: Ballard County, Kentucky. On Bradford Road 700 feet east near old railroad grade.
Geomorphic Position: Floodplain low bottom.
Slope and Aspect: 0 to 2%.
Parent Material(s): Local alluvium from loess uplands.
Vegetation: Wheat 95 and soybeans planted in wheat stubble 96.
Erosion: No evidence of recent scouring or deposition.
Described By: Lietzke.
Date: 7-10-96

Soil Description
Ap 0 to 30 cm; brown (10YR 4/3) silt loam; reduced zones around old corn stalks below the surface; surface 0 to 5 cm reduced to dark grayish brown (2.5Y 4/2); thin streaks and threads on Mn.
Cg1 30 to 50 cm; grayish brown (2.5Y 5/2) silt or silt loam; many black Mn nodules 1-10 mm in size; few yellowish brown (10YR 5/4) streaks and threads.
Cg2 50 to 110 cm; light brownish gray (2.5Y 6/2) silt loam; many 2-10 mm Mn nodules, black with Fe oxide rinds; yellowish brown (10YR 5/6) Fe streaks; few light yellowish brown (2.5Y 6/3) splotches.

**SITE No. F-12**

Map Unit Delineation: Falaya-Collins Complex
Soil Classified as: Aquic Udifluvents; coarse-silty, mixed, thermic.
Soil Series Identified as: Collins

Location: Ballard County, Kentucky. On Route 358 north of LaCenter, 500 feet from the bridge then 230 feet off the road.
Geomorphic Position: Low terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): alluvium from loess.
Vegetation: Soybeans.
Erosion: No evidence of recent scouring or deposition or erosion.
Described By: Elless.
Date: 7-15-96

Soil Description
Ap 0 to 20 cm; brown (10YR 4/3) silt loam.
Bw1 20 to 40 cm; brown (10YR 5/3-4/3) silt loam; common light gray (10YR 7/1) depletions.
Bw2 40 to 90 cm; brown (10YR 5/3) silt loam; many yellowish brown (10YR 4/6) Fe accumulations; light gray (10YR 7/1) depletions in flow zones; some Mn staining.
C 90 to 120 cm; brown (10YR 5/3) silt loam; light gray depletions in flow zones; brown (10YR 4/3) and yellowish brown (10YR 5/6) Fe accumulations; some Mn staining.

**SITE No. F-17**

Map Unit Delineation: Falaya-Collins Complex
Soil Classified as: Aeric Fluvaquents; coarse-silty, mixed, thermic.
Soil Series Identified as: Falaya

Location: Ballard County, Kentucky. West on Kirkman road off of Route 385, then 200 feet south into CRP land just converted to soybean production.
Geomorphic Position: Fairly narrow floodplain where channalization moved the old channel farther to the south.
Slope and Aspect: 0 to 2%.
Parent Material(s): Alluvium from loess.
Vegetation: Weeds from CRP land. Weeds killed by herbicide and beans no-till drilled in residue.
Erosion: Probably some recent deposition, but Ap horizon has been preserved and there are no stratified sediments above it.
Described By: Lietzke.
Date: 7-17-96

Soil Description
0 1 to 0 cm; grass and weed litter from CRP.
Ap 0 to 25 cm; brown (10YR 4/3) silt loam.
Bw 25 to 40 cm; brown (10YR 5/3) and grayish brown (10YR 5/2) silt loam; strong brown (7.5YR 5/6) Fe coatings on faces of cracks; common soft Mn concentrations.
Cg 40 to 110 cm; grayish brown (10YR 5/2) and light brownish gray (10YR 6/2) silt loam; yellowish brown (10YR 5/6), strong brown (7.5YR 5/6). and yellowish red (5YR 5/6-5/8) coatings on crack faces, as threads, and on some horizontal strata; few soft Mn concentrations.

**SITE No. F-20**

Map Unit Delineation: Falaya-Collins Complex
Soil Classified as: Typic Fluvaquents; coarse-silty, mixed, thermic.
Soil Series Identified as: Waverly

Location: Ballard County, Kentucky. On Highway 473, 146 feet off of road in soybean field.
Geomorphic Position: Floodplain.
Slope and Aspect: 0 to 2%.
Parent Material(s): Alluvium from loess.
Vegetation: Wheat 95 and soybeans 96.
Erosion: No evident scouring or deposition.
Described By: Elless
Date: 7-15-96

Soil Description
Ap 0 to 20 cm; brown (10YR 5/3-4/3) silt loam; few light gray (10YR 7/1) depletions; some charcoal present.
Cg1 20 to 40 cm; grayish brown (10YR 5/2) silt loam; yellowish brown (10YR 5/6 and strong brown (7.5YR 5/6) Fe accumulations and oxidized zones; light gray (10YR 7/1) depleted zones.
Cg2 40 to 70 cm; grayish brown (10YR 5/2) silt loam; many light gray (10YR 7/1) depletions; many yellowish brown (10YR 4/6) and strong brown(7.5YR 5/6) iron accumulations and oxidized zones.
Cg3 70 to 110 cm; grayish brown (10YR 5/2) with red (2.5YR 4.6) Fe coatings on crack faces; light gray (10YR 7/1) depletions; strong brown (7.5YR 5/6) Fe accumulations; some Mn staining. Saturation at 100 cm.
Cg4 110 to 120 cm; bluish gray (5B 6/1) silt loam; dark red (2.5YR 3/6) Fe coatings in flow zones; strong brown (7.5YR 5/6) Fe accumulations.

**SITE No. F-21**

Map Unit Delineation: Falaya-Collins Complex.
Soil Classified as: Aquic Udifluvents; coarse-silty, mixed, thermic.
Soil Series Identified as: Collins

Location: Ballard County, Kentucky. Route 358 just south of Bandana. At Bridge, 400 feet east of F-22.
Geomorphic Position: Broad floodplain. Site between major stream channel and field ditch.
Slope and Aspect: 0 to 2%.
Parent Material(s): Alluvium from loess.
Vegetation: Red clover planted in 1995.
Erosion: No evidence of recent scouring, but probably has been a slight accumulation of sediment from recent flooding.
Described By: Lietzke
Date: 7-18-96

Soil Description
Ap 0 to 25 cm; brown (10YR 4/3) silt loam.
Bw1 25 to 50 cm; brown (10YR 4/3 and 10YR 5/3) silt loam; soft Mn accumulations.
Bw2 50 to 65 cm; brown (10YR 5/3) silt loam; areas of Mn concentrations.
Cg 65 to 110 cm; light brownish gray (10YR 6/2) silt loam; areas of brown (10YR 5/3); many soft Mn concentrations and harder Mn nodules 3-8 mm in diameter; yellowish brown (10YR 5/6) Fe steaks below 80 cmI strong brown (7.5YR 4/6) Fe accumulations; light gray (10YR 7/1) depletions.

**SITE No. F-22**

Map Unit Delineation: Waverly
Soil Classified as: Typic Fluvaquents; coarse-silty, mixed, thermic.
Soil Series Identified as: Waverly

Location: Ballard County, Kentucky. Route 358 just south of Bandana at bridge, then 150 feet into field and 40 feet south of channel embankment.
Geomorphic Position: Broad floodplain.
Slope and Aspect: 0 to 2%.
Parent Material(s): Alluvium from loess.
Vegetation: Red clover planted in 1995.
Erosion: No evidence of recent scour, but there has probably been some slight deposition from recent flooding.
Described By: Lietzke.
Date: 7-11-96

Soil Description
Ap 0 to 25 cm; brown (10YR 4/3) sit loam.
Bwg 25 to 45 cm; light brownish gray (10YR 6/2) silt loam; few yellowish brown (10YR 5/6) Fe accumulations and common hard Fe-Mn nodules.
Cg 45 to 120 cm; light brownish gray (10YR 6/2) silt or silt loam; pale brown (10YR 6/3) more oxidized splotches; light gray (10YR 7/1) depletions; few hard Mn-Fe nodules.

**SITE No. F-23**

Map Unit Delineation: Falaya-Collins Complex.
Soil Classified as: Aeric Fluvaquents; coarse-silty, mixed, thermic.
Soil Series Identified as: Falaya

Location: Ballard County, Kentucky. From Bandana, take Allen street south to where it ends at the creek, then follow the creek westerly about 1,000 feet, then 200 feet north into the field. This site is nearly due south of the Bandana Methodist Church.
Geomorphic Position: Low terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Alluvium from loess.
Vegetation: Corn 95, wheat 95, and soybeans 96.
Erosion: No evidence of recent scouring or recent deposition.
Described By: Lietzke.
Date: 7-9-96

Soil Description
Ap 0 to 20 cm; dark brown (10YR 4/4) silt loam.
Bw 20 to 40 cm; brown (10YR 4/3) silt loam; grayish brown (10YR 5/2) depletions.
Cg 40 to 58 cm; light grayish brown (10YR 6/2) silt loam; brown (10YR 5/3) oxidized areas.
C1 58 to 90 cm; brown (10YR 5/3) silt loam; yellowish brown (10YR 5/8) Fe accumulations; light gray (10YR 7/2) depletions.
C2 90 to 120 cm; brown (10YR 5/3) and pale brown (10YR 6/3) silt loam; light gray (10YR 7/2) depletions; yellowish brown (10YR 5/6-5/8) Fe accumulations.

**SITE No. F-29**

Map Unit Delineation: Falaya-Collins Complex.
Soil Classified as: Aquic Udifluvents; coarse-silty, mixed, thermic.
Soil Series Identified as: Collins

Location: Ballard County, Kentucky. At Needmore, turn off Monkey Eyebrow Road south onto Marrow Road to where this road crosses the ditch. then follow the ditch on the north side for about 120 feet then 50 feet north.
Geomorphic Position: Fairly narrow floodplain where the creek channel has been straightened.
Slope and Aspect: 0 to 2%.
Parent Material(s): Alluvium from loess.
Vegetation: CRP land. Tall grass and weeds.
Erosion: No evidence of recent scouring or deposition.
Described By: Lietzke
Date: 7-18-96

Soil Description
Ap 0 to 25 cm; brown (10YR 5/3) silt loam.
Bw 25 to 60 cm; brown (10YR 5/3) silt loam; light gray (10YR 7/1) and grayish brown (10YR 5/2) depletions.
C 60 to 90 cm; brown (10YR 5/3) silt loam; strong brown (7.5YR 5/6) Fe accumulations on crack faces; few soft Mn nodules; yellowish red (5YR 4/6) coatings and threads; grayish brown (10YR 5/20 depletions.
Cg 90 to 110 cm; light gray (10YR 6/1) silt loam; splotchy areas of brown (10YR 5/3); soft Mn stains and accumulations; black Mn coatings on some crack faces.

**SITE No. H-1**

Map Unit Delineation: Henry
Soil Classified as: Aeric Glossaqualfs or Aeric Epiaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Keck

Location: Ballard County, Kentucky. On Highway 473 east to Reid Road intersection then continue east past soybean field to woods.
Geomorphic Position: Low area on broad terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess.
Vegetation: Hardwoods.
Erosion: None.
Described By: Elless.
Date: 7-15-96

Soil Description
Oe 3 to 0 cm; leaf litter.
A 0 to 15 cm; dark grayish brown (10YR 4/2) silt loam.
E1 15 to 40 cm; brown (10YR 5/3) silt loam; few light gray (10YR 7/1) depletions; few to common 2-5 mm diameter Fe-Mn nodules.
E2 40 to 60 cm; pale brown (10YR 6/3) silt loam. light gray (10YR 7/1) depletions; yellowish brown (10YR 5/6) Fe accumulations; common 2-5 mm diameter Fe-Mn nodules.
Btg 60 to 110 cm; grayish brown (10YR 5/2) silty clay loam; light gray (10YR 7/1) depletions; yellowish brown (10YR 5/6) Fe accumulations; common Fe-Mn nodules.
Bt 110 to 120 cm; brown (10YR 5/3) silty clay loam; light gray (10YR 7/1) depletions; strong brown (7.5YR 5/8) Fe accumulations; common Fe-Mn nodules.

**SITE No. H-2**

Map Unit Delineation: Henry
Soil Classified as: Typic Glossaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Routon

Location: Ballard County, Kentucky. East on Route 473 to Reid Road. Turn left on Reid Road to where it turns west. Continue North on private driveway past office building and barn to the woods in back of the barn. Site is 170 feet north of the south edge of the woods and 150 feet east of the west edge of the woods.
Geomorphic Position: Low area in broad terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess.
Vegetation: Hardwoods.
Erosion: None and no evidence of overwash.
Described By: Lietzke.
Date: 7-16-96.

Soil Description
O 1 to 0 cm; leaf litter.
A 0 to 10 cm; brown (10YR 4/3) silt loam; grayish brown (10YR 5/2) depletions.
Eg 10 to 40 cm; light gray (10YR 7/1) silt loam; few hard Mn nodules.
Btg &Eg 40 to 60 cm; light gray (10YR 7/1) silty clay loam B part, and white (10YR 8/1) silt E part.
Btg 60 to 120 cm; light gray (10YR 7/1) silty clay loam; white (10YR 8/1) highly depleted flow zones.

**SITE No. H-3**

Map Unit Delineation: Henry
Soil Classified as: Aeric Epiaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Kurk

Location: Ballard County, Kentucky. On Kirkham Road, then 75 feet west into woods.
Geomorphic Position: Low area on broad terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess.
Vegetation: Hardwoods.
Erosion: None.
Described By: Elless.
Date: 7-15-96

Soil Description
Oe 2 to 0 cm; leaf litter.
A 0 to 12 cm; brown (10YR 4/3) silt loam.
E1 12 to 35 cm; brown (10YR 5/3-4/3) silt loam; light gray (10YR 7/1) depletions; yellowish brown (10YR 5/6) Fe accumulations.
E2 35 to 50 cm; brown (10YR 5/3) silt loam; light gay (10YR 7/1) depletions; yellowish brown (10YR 5/6) Fe accumulations.
Bt1 50 to 90 cm; brown (10YR 5/3) silty clay loam; light gray (10YR 7/1) depletions; yellowish red (5YR 5/6) Fe accumulations; common 2-5 mm Fe-Mn nodules.
Bt2 90 to 120 cm; yellowish brown (10YR 5/4-5/6) silty clay loam; light brownish gray (10YR 6/2) depletions; strong brown (7.5YR 5/6) Fe accumulations.

**SITE No. H-4**

Map Unit Delineation: Henry
Soil Classified as: Typic Ochraqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Routon

Location: Ballard County, Kentucky. In Town of Bandana on College Street, turn south onto Allen Street. Go south until street ends at creek, go east into woods. Site is about 300 feet north of creek and 300 feet east of Allen Street.
Geomorphic Position: Low area on broad terrace. Site is close to modern floodplain.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess and alluvium from loess.
Vegetation: Hardwoods.
Erosion: None, but there may be some overwash deposition.
Described By: Lietzke.
Date: 7-10-96

Soil Description
O 1 to 0 cm; leaf litter.
A 0 to 10 cm; dark grayish brown (10YR 4/2) silt loam.
Eg 10 to 58 cm; light brownish gray (2.5Y 6/2) silt or silt loam; thin Mn streaks, threads and hard nodules.
Btg 58 to 80 cm; grayish brown (2.5Y 5/2) silty clay loam; white (5Y 8/1) depletions on surfaces of peds; some very small hard Mn nodules.
C 80 to 95 cm; light olive brown (2.5Y 5/3) stratified silt loam and silty clay loam; common black hard Mn nodules 1.2 mm in diameter.
2Bt 95 to 110 cm; light olive brown (2.5Y 5/3) silty clay loam; many yellowish brown (10YR 5/6) Fe accumulations; common hard black Mn nodules.

**SITE No. H-5**

Map Unit Delineation: Henry
Soil Classified as: Typic or Aeric Epiaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Routon

Location: Ballard County, Kentucky. On Gibson Road south of Clanton Creek to farm buildings. Follow fencerow west along field and woods to cross fence, come back east 150 feet then 100 feet north into woods.
Geomorphic Position: Low area on terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess and alluvium from loess.
Vegetation: Hardwoods.
Erosion: None, but overwash from flooding of Clanton Creek may be possible.
Described By: Lietzke.
Date: 7-11-96

Soil Description
O 1 to 0 cm; leaf litter.
A 0 to 10 cm; dark brown (10YR 3/3) silt loam.
E1 10 to 40 cm; brown (10YR 5/3) silt loam; light brownish gray (10YR 6/2) depletions; yellowish brown (10YR 5/6) FE accumulations.
E2 40 to 60 cm; grayish brown (10YR 5/2) and brown (10YR 5/3) silt loam; light brownish gray (10YR 6/2) depletions; yellowish brown (10YR 5/6) Fe accumulations.
Btg 60 to 95 cm; grayish brown (10YR 5/2) silt loam or silty clay loam; light gray (10YR 7/2) depletions; yellowish brown (10YR 5/6) Fe accumulations.
Bt 95 to 120 cm; brown (10YR 5/3) silty clay loam; light gray (10YR 7/2) depletions; yellowish brown (10YR 5/6) Fe accumulations.

**SITE No. H-6**

Map Unit Delineation: Henry
Soil Classified as: Typic Glossaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Routon

Location: Ballard County, Kentucky. At the intersection of Gibson Road and Clanton Creek, south to fencerow on west side. Follow fence row through filed on north side of fencerow to edge of woods. Then 300 feet north from south edge of field, then 100 feet into woods.
Geomorphic Position: Low area on broad terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess and alluvium from loess.
Vegetation: Hardwoods.
Erosion: None, but there may be overwash from Clanton Creek floods.
Described By: Lietzke.
Date: 7-11-96

Soil Description
O 1 to 0 cm; leaf litter and debris.
A 0 to 10 cm; very dark grayish brown(10YR 3/2) silt loam.
E1 Grayish brown (10YR 5/2) silt loam; strong brown (7.5YR 5/8) Fe accumulations; no Mn observed.
E2 35 to 60 cm; brown (10YR 5/3) silt loam; light brownish gray (10YR 6/2) depletions; yellowish brown (10YR 5/6) Fe accumulations.
Btg&E 60 to 95 cm; grayish brown (10YR 5/2) silty clay loam B part and light gray (10YR 7/1) E part; strong brown (7.5YR 5/8) Fe accumulations; hard Mn nodules 1-2 mm in diameter.
Bt 95 to 120 cm; yellowish brown (10YR 5/4) silty clay loam; light brownish gray (10YR 6/2) depletions; strong brown (7.5YR 5/8) Fe accumulations; hard Mn nodules.

**SITE No. H-7**

Map Unit Delineation: Henry
Soil Classified as: Typic Glossaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Routon

Location: Ballard County, Kentucky. At intersection of Clanton Creek and Gibson Road. Go west along edge of field next to the creek to the edge of the woods. then 160 feet south and then 50 feet into woods.
Geomorphic Position: Low area on broad terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess and alluvium from loess.
Vegetation: Hardwoods.
Erosion: None but some recent overwash deposition from flooding of Clanton Creek.
Described By: Lietzke.
Date: 7-11-96

Soil Description
O 2 to 0 cm; leaf litter.
A 0 to 10 cm; grayish brown (10YR 5/2) silt loam; yellowish brown (10YR 5/6) streaks.
Eg1 10 to 25 cm; light gay (10YR 6/1) silt loam; yellowish brown (10YR 5/6 Fe streaks; few black Mn streaks.
Eg2 25 to 50 cm; grayish brown (10YR 5/2) silt loam.
E& Btg 50 to 70 cm; white (10YR 8/1) silt E part, and light gray (10YR 7/1) silt loam, B part.
Btg&E 70 to 100 cm; light brownish gray (10YR 6/2) B part and light gray (10YR 7/1) silt loam E part; common to many 2-5 mm diameter Mn nodules; abundant roots.
Btg 100 to 120 cm; light brownish gray (10YR 6/2) silt loam; light gray (10YR 7/1) depleted areas; common roots.

**SITE No. H-9**

Map Unit Delineation: Henry
Soil Classified as: Typic Ochraqualfs or Typic Glossaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Routon

Location: Ballard County, Kentucky. At the intersection of Gibson and Vaughn Roads turn east onto Vaughn Road to woods on south side of the road. Site is 170 feet east of west edge of woods and then 100 feet south of road.
Geomorphic Position: Low area on broad terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess.
Vegetation: Hardwoods.
Erosion: None.
Described By: Lietzke
Date: 7-11-96

Soil Description
O 2 to 0 cm; leaf litter.
A 0 to 2 cm; brown (10YR 5/3) silt loam.
Eg1 2 to 45 cm; grayish brown (10YR 5/2) silt loam; yellowish brown (10YR 5/8) Fe accumulations; no Mn nodules.
Eg2 Light gray (10YR 6/1) silt or silt loam; dark yellowish brown (10YR 4/6) Fe accumulations; white (10YR 8/1) depleted areas.
Btg 60 to 120 cm; light gray (10YR 6/1) silty clay loam; few dark yellowish brown (10YR 4/6) Fe accumulations; few Mn nodules 1-2 mm in diameter.

**SITE No. H-10**

Map Unit Delineation: Henry
Soil Classified as: Typic Epiaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Routon

Location: Ballard County, Kentucky. At the intersection of Gibson and Vaughn roads, turn east on Vaughn road to the woods on the south side of Vaughn Road. Go to the east side of the woods, then south along the edge of the woods 230 feet then 75 feet west into woods.
Geomorphic Position: Low area on broad terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess.
Vegetation: Hardwoods.
Erosion: None.
Described By: Elless.
Date: 7-15-96

Soil Description
O 2 to 0 cm; leaf litter.
A 0 to 8 cm; brown (10YR 4/3) and dark brown (10YR 3/3) silt loam.
E 8 to 40 cm; brown (10YR 4/3) with light gray (10YR 7/1) depletions; yellowish brown (10YR 5/6) Fe accumulations; few very small 1 mm Mn nodules.
Eg 40 to 60 cm; grayish brown (10YR 5/2) silt loam; light gray (10YR 7/1) depletions; yellowish brown (10YR 5/6) Fe accumulations.
Btg 60 to 90 cm; grayish brown (10YR 5/2) silty clay loam; light gray (10YR 7/1) depletions; yellowish brown (10YR 5/6) Fe accumulations.
Bt 90 to 120 cm; brown (10YR 5/3) silty clay loam; with light brownish gray (10YR 6/2) depletions; yellowish brown (10YR 5/8) Fe accumulations; soft, 3-5 mm diameter Mn nodules.

**SITE No. H-13**

Map Unit Delineation: Henry
Soil Classified as: Typic Glossaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Routon

Location: Ballard County, Kentucky. At the intersection of Ogden-Colvin Road with Monkey Eyebrow Road, continue west on Monkey Eyebrow Road about a quarter mile to a field road on south. Turn south on field road to woods. Site is 50 feet east of west side of woods and 60 feet south of north edge of woods.
Geomorphic Position: Low area on broad terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess.
Vegetation: Hardwoods.
Erosion: None.
Described By: Lietzke.
Date: 7-17-96

Soil Description
O 2 to 0 cm; leaf litter.
A 0 to 10 cm; very dark grayish brown (10YR 3/2) silt loam.
Eg 10 to 50 cm; grayish brown (10YR 5/2) and light gray (10YR 6/2) silt loam; numerous small Mn nodules; few yellowish brown (10YR 5/6) Fe accumulations.
Eg&Bg 50 to 70 cm; light gray (10YR 7/1) E part and grayish brown (10YR 5/2) silt loam B part; yellowish brown (10YR 5/6) Fe accumulations; hard Mn nodules.
Btg&Eg 70 to 90 cm; grayish brown (10YR 5/2) B part and light gray (10YR 7/2) silt loam E part; light gray (10YR 7/1 highly depleted flow zones; yellowish brown (10YR 5/6) Fe accumulations; small hard Mn nodules.
Btg 90 to 110 cm; light brownish gray (10YR 6/1) silty clay loam; light gray (10YR 7/1) depleted areas; yellowish brown (10YR 5/6) Fe accumulations; small hard Mn nodules.

**SITE No. H-15**

Map Unit Delineation: Henry
Soil Classified as: Typic Glossaqualfs or Typic Epiaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Routon

Location: Ballard County, Kentucky. From the intersection of Maloy and Throgmorton Roads. Continue east on Throgmorton Road to woods on south side of road. Site is 120 feet west of east edge of the woods and 160 feet south of road.
Geomorphic Position: Low area on broad terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess.
Vegetation: Hardwoods.
Erosion: None
Described By: Lietzke.
Date: 7-17-96

Soil Description
O 3 to 0 cm; leaf litter.
A 0 to 10 cm; brown (10YR 4/3) silt loam.
Eg 10 to 30 cm; light brownish gray (10YR 6/2) silt loam; many hard Mn nodules; yellowish brown (10YR 5/6) Fe accumulations.
Btg 30 to 70 cm; grayish brown (10YR 5/2) silty clay loam; yellowish brown (10YR 5/6) Fe accumulations; few hard Mn nodules.
Bt 70 to 110 cm; brown (10YR 5/3) and yellowish brown (10YR 54/6) silty clay loam; light gray (10YR 7/1) siltans; light gray (10YR 6/1) highly depleted flow zones; no Mn nodules.

**SITE No. H-18**

Map Unit Delineation: Henry
Soil Classified as: Typic Glossaqualfs; fine-silty, mixed, thermic.
Soil Series Identified as: Routon

Location: Ballard County, Kentucky. Turn north on Ogden-Colvin Road off of Monkey Eyebrow Road. Continue about 1 mile to field road on right. Turn east onto field road for about one quarter mile to woods beyond pond. Site is i the middle of the woods and 100 feet south of north woods edge.
Geomorphic Position: Low area on broad terrace.
Slope and Aspect: 0 to 2%.
Parent Material(s): Loess.
Vegetation: Hardwoods.
Erosion: None.
Described By: Lietzke.
Date: 7-17-96

Soil Description
A 0 to 10 cm; very dark grayish brown (10YR 3/2) silt loam
Eg1 10 to 30 cm; grayish brown (10YR 5/2) silt loam; yellowish brown (10YR 5/6) Fe accumulations; few Mn hard nodules.
Eg2 30 to 70 cm; grayish brown (10YR 5/2) silt loam; few yellowish brown (10YR 5/6) Fe accumulations; many fine Mn nodules; light gray (10YR 7/1) siltans.
Btg 70 to 110 cm; brown (10YR 5/3) and light brownish gray (10YR 6/2) silty clay loam; strong brown (7.5YR 5/6) and yellowish brow (10YR 5/6) Fe accumulations; light gray (10YR 7/1) highly depleted flow zones; no Mn nodules.

# APPENDIX B

# SITE LOCATIONS AND PROFILE DESCRIPTIONS
# HYDROGEOLOGIC UNITS

# LOCATION OF CORING SITES

The initial location of all deep drilling sites was specified on page 29 of The Plan (DOE/OR/07-1414&D2). However, the Paducah grid coordinates for the first of the two drill sites near well #194 were not adhered to. Accordingly, by the time the sampling team of S.Y. Lee, Mark Elless and D.A. Lietzke had arrived, the first core, 194-01, had been collected. This first drill site was located 36 feet west of Monitoring Well #194, and 5 to 6 feet off of the limestone gravel pad around this well. The primary problems with this drill site were: (1) the closeness to the creek and possible contamination, (2) the site was located in a creek floodplain and (3) no HU-1 loess would be sampled. However, after considerable discussion, a decision was made to use the existing 194-01 core and to obtain another core, 194-02, within a distance of 24 inches. The rationale for using this particular floodplain site was that background could be obtained on HU-1 alluvium.

Ten cores were taken from five sites (two cores were take in rather close promity to act as duplicate cores). A perspective of the location of each of the coring sites is illustrated in Fig. B.1. The location of each core site is presented in Table B.1. below.

**Table B.1. Plant grid locations for coring sites**

| Core Site | Plant Grid X | Plant Grid Y |
|---|---|---|
| 194-01 | W 10208 | N 01770 |
| 194-02 | W 10275 | N 01770 |
| 194-03 | W 111790 | S 01300 |
| 194-04 | W 11789 | S 01301 |
| 194-05 | W 12600 | S 02090 |
| 194-06 | W 12607 | S 02090 |
| 196-01 | W 07780 | S 07920 |
| 196-02 | W 07782 | S 07922 |
| 196-03 | W 07780 | S 07500 |
| 196-04 | W 08200 | S 07820 |

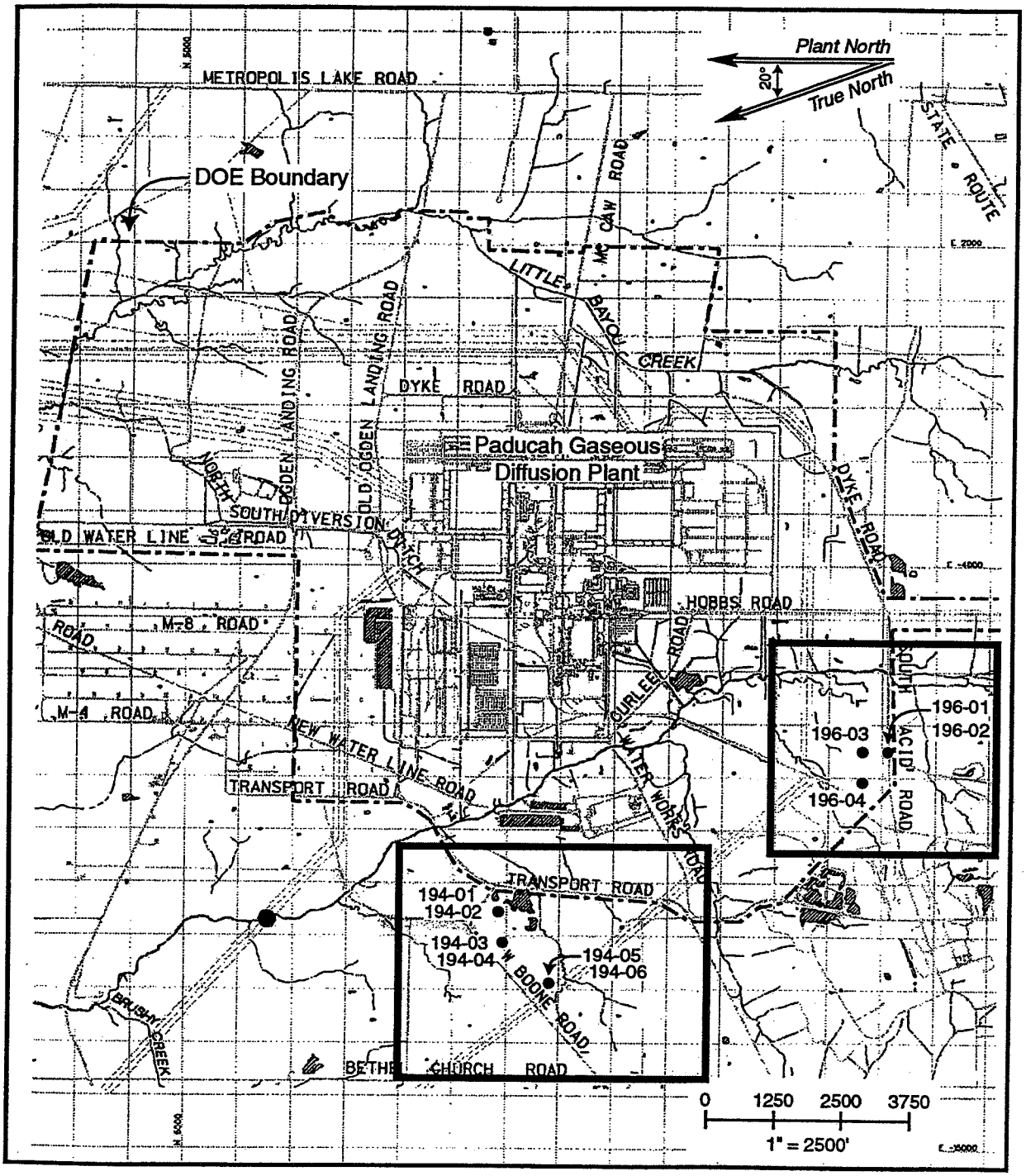


**Fig. B.1. Location of drill core sites.**

## DESCRIPTIONS AND LOGS FOR DEEP CORE SAMPLES

**Log of Core 194-01**

Core Description

0' 0" to 0' 6" Ap horizon; dark brown (10YR 3/3) sandy loam with roots and both limestone gravels and chert gravels.

0' 6" to 1' 23" C Horizon; brown (10YR 4/3) sandy loam or loam with grayish brown (10YR 5/2) iron depletions and strong brown (7.5YR 4/6) iron threads and accumulations around chert gravels. A 2 inch thick silt and very fine sand strata occurred in this section, but may have been pushed there. It fits better with the core section beginning at a depth of 4I

1' 23" to 4' 0" Missing section.

4' 0" to 5' 0" Light yellowish brown (2.5Y 6/3) silt and very fine sand with dark yellowish brown (10YR 4/6) Fe coatings and threads; few 1 cm diameter very dark grayish brown (10YR 3/2) Mn accumulations; no hard nodules.

5' 0" to 6' 9" Brown (10YR 5/3) very fine sand, fine sand and silt without gravel fragments; large light brownish gray (10YR 6/2) Fe depletions; thin yellowish brown (10YR 5/4) diffuse Fe accumulations. This section is gradational with increasing grain size with depth. The section from 6' 0" to 6' 9" consists of fine sand, very fine sand and minor silt. BASE OF HU-1

6' 9" to 7' 6" Pale brown (10YR 6/3) sandy loam having a high content of medium sand; large pores and vesicles; light gray (10YR 7/2) stripped sand grains; no coarse fragments.

7' 6" to 8' 0" Light gray (10YR 7/2) and light olive brown (2.5Y 5/3) sandy loam with a few 0.5 to 1 cm diameter chert gravels; dark yellowish brown (10YR 4/6) Fe accumulations.

8' 0" to 9' 0" Light gray (10YR 7/1) very gravelly sandy clay loam with very low silt fine sand and very fine sand content and high medium and coarse sand content; many gravels up to 1.5 cm in mean diameter; yellowish brown (10YR 5/8) Fe accumulations and oxidized zones. This is a zone that perches water.

9' 0" to 11' 0" Light gray (10YR 7/1) and yellowish brown (10YR 5/6) in large splotches; sandy clay loam dominated by medium sand; few fine rounded gravels less than 0.5cm in diameter. BASE OF HU-2.

Note: There is a mixing zone beginning at 10' 9" to 11' 3".

11' 0" to 12' 3" Yellowish brown (10YR 5/4) silty clay loam with loss of gravel, medium sand and fine sand and large increase in silt and clay content; gray (10YR 6/1) Fe depleted zones and strong brown (7.5YR 4/6) Fe accumulations and oxidized zones with sharp boundaries between zones; yellowish red (5YR 4/6) coatings and a few harder Fe nodules.

12' 3" to 17' 6" Gray (10YR 6/1) and light gray (10YR 7/1) silty clay loam or silty clay with very low sand content; yellowish brown (10YR 5/4) oxidized splotches and yellowish brown (10YR 5/8) Fe accumulations about 1 mm in size becoming strong brown (7.5YR 4/6) in the lower part.

17' 6" to 18' 0" Light gray (10YR 7/1) clay with yellowish red (5YR 4/6) Fe nodules and gray (10YR 6/1 and 5/1) steaks at the base of this section.

18' 0" to 20' 0" Yellowish red (5YR 4/6) and strong brown (7.5YR 4/6) clay or clay loam with some gravels and a higher sand content; gray (10YR 6/1) and light brownish gray (10YR 6/2) Fe depleted flow zones and gray (10YR 5/1) clay flows. BASE OF CORE.

HU-1 Modern and Late Holocene alluvium 0 to 6' 9".
HU-2 Upper Continental deposits 6' 9" to 11' 0".
HU-3 Lower Continental deposits 11' 0" to bottom of core.

Samples collected:

| | | |
|---|---|---|
| 101095 | HU-1 | 0' 6" to 6' 9" |
| 101096 | HU-2A | 6' 9" to 9' 0" |
| 101097 | HU-2B | 9' 0" to 11' 0" |
| 101099 | HU-3A | 11' 10" to 20' 0" |

Notes:

HU-1 The Modern and Late Holocene alluvium is a coarsening upwards sequence.The lower section of the alluvium is dominated by loess. Headwards erosion of the creek and downcutting brought the creek into contact with continental gravels and Eocene sands. There is an abrupt change from HU-1 to HU-2. The upper approximately 4 feet consists of Modern alluvium. From 4' 0" to 6' 9" the alluvium consists of mostly reworked loess. The base of HU-1 occurs at a depth of 6' 9" with an abrupt change in particle size of the sand fraction and loss of most silt content

HU-2 This unit is dominated by medium sand sized particles and definite stratification with one very gravelly strata. There is a mixing zone about 6 inches thick with the HU-3 beneath.

HU-3 This unit consists of firm high silt and clay content alluvium or lacustrine sediments. The upper section of this unit is fairly well oxidized; the middle part is dominantly deoxidized and the lower part is in a higher re-dox potential. This lower oxidized section also has a higher sand and gravel content.

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**CORE 194-02**

This core was collected at a distance of 18 to 24 inches to the west of core 194-01.

Core Description.

0' 0" to 0' 6" Ap horizon; brown (10YR 4/3) gravelly loam or gravelly sandy loam with rounded chert gravels that are clean and oxide coated.

0' 6" to 1' 3" C horizon; dark yellowish brown (10YR 4/4) sandy loam or loam with brown (10YR 5/3) depleted flow zones; perched water zone at the base where very dark brown (10YR 2/2) Mn has accumulated; also some Fe coatings on gravel surfaces.

1' 3" to 4' 0" Light olive brown (2.5Y 5/3) stratified silt and very fine sand; yellowish brown (10YR 5/6) Fe threads and splotches; no evident Mn concentrations.

4' 0" to 5' 11" Brown (10YR 5/3) stratified silt and very fine sand with very dark brown (10YR 2/2) Mn diffused in bands; no visible Fe accumulations or depletions; silt content decreases with depth and very fine sand and fine sand content increases, but no medium or coarser sized sand particles. At the base of this section there are light gray (10YR 7/2) depletions and a few dark yellowish brown (10YR 4/6) Fe accumulations. BASE OF HU-1.

5' 11" to 8' 1" Light gray (10YR 7/2) and brown (10YR 5/3) in a splotchy pattern; soil texture is sandy loam; bleached out and stripped areas greatly depleted in oxides; many 1-3 cm diameter soft Mn concentrates of dark brown (10YR 3/3) and dark yellowish brown (10YR 4/3).

5' 11" to 6' 4" Strata dominated by fine sand

6' 4" to 7' 3" Strata dominated by medium sand.

7' 3" to 7' 11" Strata dominated by medium sand and fine gravel.

7' 11" to 8' 1" Strata of loose coarse sand and gravel

8' 1" to 8' 11" Light brownish gray (10YR 6/2) very gravelly sandy clay loam with gray (10YR 6/1) clay flows and small thin yellowish brown (10YR 5/6) Fe threads. This section is clay plugged.

8' 11" to 11' 4" Yellowish brown (10YR 5/4) sandy clay loam without any gravels; gray (10YR 6/1) clay flows in light brownish gray (10YR 6/2) flow zones; high medium sand content; thin strata of yellowish brown (10YR 5/6) sandy loam at the base of HU-2.

Abrupt transition to HU-3 beneath.

| | |
|---|---|
| 11' 4" to 12' 0" | Yellowish brown (10YR 5/6) and gray (5Y 6/1) in large splotches; silty clay or clay without medium or fine sand. |
| 12' 0" to 16' 1" | Gray (10YR 6/1) and yellowish brown (10YR 5/4) and light yellowish brown (10YR 6/4) in large splotches; silty clay loam or silty clay. |
| 16' 1" to 18' 7" | Gray (10YR 6/1) with brown (10YR 5/3) oxidized zones; silty clay or silty clay loam; strong brown (7.5YR 5/8) Fe oxide coatings and threads in the lower part. |
| 18' 7" to 18' 9" | Gray (10YR 6/1) and (10YR 5/1) clay with some sand particles; strong brown (7.5YR 4/6 and 5/8) splotches in the lower part. Transition to flow zone beneath. |
| 18' 9" to 20' 0" | Strong brown (7.5YR 4/6 and 7.5YR 5/8) clay loam with thick Fe oxidized zones; noticeable increase in sand content; gray (N5/) clay flows. Flow zone. BASE OF CORE. |

Samples collected.

| | | |
|---|---|---|
| 101100 | HU-1 | 1' 5" to 5' 11" |
| 101101 | HU-2A | 5' 11" to 8' 11" |
| 101102 | HU-2B | 8' 11" to 11' 4" |
| 101103 | HU-3A | 1' I4" to 18' 7" |
| 101104 | HU-3B | 18' 7" to 20' 0" |

Notes:
HU-1 is undifferentiated loess. Based in the lack of any Mn nodules the age of this loess is Peorian or very early Holocene.
HU-2 is interpreted as alluvium based on evident stratification, gravel strata and fairly high medium sand content. In this core, the alluvium is a fining upwards sequence.
HU-3 is interpreted as lacustrine origin in the upper part although at a depth of 18' 7" there is a noticeable increase in sand content.

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**CORE 194-03**

This drill sit is located on the south side of west Boone road about 100 feet south. Grid coordinates are those specified on page 29 of The Plan. The site is located in a map unit delineation of Calloway soils and close to a shallow drainageway. The soil classification at this site places the soil that formed in loess within the Keck series.

Core Description

| | |
|---|---|
| 0' 0" to 0' 7" | Ap Horizon; light olive brown (2.5Y 5/4) silt loam with hard Mn nodules. |
| 0' 7" to 2' 0" | Btg Horizon; light brownish gray (2.5Y 6/2) silty clay loam with pale brown (10YR 5/3) deoxidized flow zones and dark yellowish brown (10YR 4/6) Fe accumulations. |
| 2' 0" to 6' 0" | Missing sections in loess due to low bulk density or part of core slipping out of the sleeve as the tube was being removed from the bore hole. |
| 6' 0" to 7' 6" | C Horizon; yellowish brown (10YR 5/4) silt loam with grayish brown (10YR 5/2) flow zones. BASE OF PEORIAN LOESS. |
| 7' 6" to 8' 0" | Yellowish brown (10YR 5/4) silty clay loam with dark yellowish brown (10YR 4/6) Fe oxide accumulations and grayish brown (10YR 5/2) clay flows. BASE OF HU-1. |
| 8' 0" to 12' 9" | Grayish brown (10YR 5/2) silty clay loam with a few small chert fragments; no sand size coarser than fine sand. Gray (10YR 6/1) clay flows; few soft black Mn nodules with a dark yellowish brown (10YR 4/6) Fe oxide rind about 1 mm thick. |
| 12' 9" to 13' 6" | Grayish brown (10YR 5/2) silty clay loam with increased yellowish brown (10YR 5/6) Fe accumulations; few to common black Mn threads. |

13' 6" to 17' 0" Light olive brown (2.5Y 5/4) silty clay loam with a few well rounded chert fragments; thin light brownish gray (2.5Y 6/2) depleted flow zones and yellowish brown (10YR 5/6) Fe accumulations that are 1-2 mm thick.

17' 0" to 18' 5" Light olive brown (2.5Y 5/3) silty clay loam with a few small coarse sand or very coarse sand sized angular chert fragments; thin light brownish gray (2.5Y 6/2) depleted flow zones 1-2 mm thick.

18' 5" to 20' 0" Light gray (10YR 6/1) silty clay loam with gray (10YR 5/1) clay flows and large splotches of yellowish brown (10YR 5/8) Fe oxidized accumulations. BASE OF CORE.

Samples Collected:

| | | |
|---|---|---|
| 101105 | HU-1 | 6' 0" to 8' 0" |
| 101106 | HU-2A | 8' 0" to 12' 0" |
| 101107 | HU-2B | 12'0" to 16' 0" |
| 101108 | HU-2C | 16' 0" to 20' 0" |

Notes:
HU-1 is interpreted to be mostly Peorian loess. An older loess was identified at the base of this section.
HU-2 is interpreted to be continental alluvium. This alluvium may also include some reworked loess based on the high silt content and low medium sand content. The chert fragments were used to make a positive identification of alluvium.
HU-3 was not identified in this core.

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**CORE 194-04**

This core was collected 12 to 24 inches away from core 194-03.

Core Description.

0' 0" to 0' 6" Ap Horizon; light olive brown (2.5Y 5/4) silt loam.

0' 6" to 3' 2" Bt Horizon; light olive brown (2.5Y 5/3) and light brownish gray (2.5Y 6/2) silty clay loam; yellowish brown (10YR 5/6) oxidized zones; few small hard Mn nodules.

3' 2" to 6' 0" C1 Horizon; yellowish brown (10YR 5/4) silt loam; pale brown (10YR 5/3) and grayish brown (10YR 5/2) depleted flow zones; few yellowish brown (10YR 5/6) Fe accumulations.

6' 0" to 7' 0" C2 Horizon; pale brown (10YR 5/3) silt loam; thin light brownish gray (10YR 6/2) flow zones and very dark grayish brown (10YR 3/2) Mn accumulations in irregular splotches. BASE OF PEORIAN LOESS.

7' 0" to 8' 1" Brown (10YR 4/3) silty clay loam; highly contrasting gray (10YR 6/1) depleted zones and yellowish brown (10YR 5/6) oxidized zones; many grayish brown (10YR 5/2) clay flows. BASE OF HU-1.

8' 1" to 11' 3" Pale brown (10YR 5/3) silt loam or light silty clay loam with a few chert fragments; numerous light gray (10YR 6/1) depleted flow zones and gray (10YR 5/2) clay flows in these flow zones; small yellowish brown (10YR 5/6) Fe accumulations.

11' 3" to 12' 0" Pale brown (10YR 5/3) silty clay loam; increased amount of diffuse Mn accumulations and a few firm strong brown (7.5YR 4/6) Fe accumulations.

12' 0" to 13' 9" Light brownish gray (10YR 6/2) silty clay loam with a few chert fragments; thin dark yellowish brown (10YR 4/6) Fe accumulations; few gray (10YR 5/1) clay flows in flow zones.

13' 9" to 16' 0" Light brownish gray (10YR 6/2) silty clay loam with a few chert fragments; many large yellowish brown (10YR 5/6) splotches; light gray (10YR 6/1) clay flows.

16' 0" to 16' 9" Pale brown (10YR 5/3) silty clay loam with light brownish gray (10YR 6/2) flow zones.

16' 9" to 17' 3" Light brownish gray (10YR 6/2) heavy silty clay loam with a few well rounded pebbles; thin yellowish brown oxidized zones and light gray (10YR 6/1) clay flows in pores and flow zones.

17' 3î to 18' 9" Yellowish brown (10YR 5/8) sandy clay loam or light sandy clay; pale brown (10YR 5/3) and light brownish gray (10YR 6/1) splotches.

18' 9" to 20' 0" Light brownish gray (10YR 6/2) silty clay loam with pale brown (10YR 5/3) more oxidized zones; highly contrasting (7.5YR 4/6) Fe accumulations and gray (10YR 5/1) clay flows; large splotches of yellowish brown (10YR 5/4) oxidized zones.

20' 0" to 21' 0" Yellowish brown (10YR 5/6) very gravelly coarse sandy loam with thick (2-3 mm) light gray (10YR 6/1) clay flows. BASE OF HU-2.

21' 0" to 24' 0" Very stiff and very firm highly mottled yellowish brown (10YR 5/6) and light brownish gray (10YR 6/2) heavy silty clay loam or silty clay; gray (10YR 5/1) clay flows; vertical strong brown (7.5YR 4/6) Fe zones surrounded by pale brown (10YR 5/3) material and light gray (10YR 7/1) flow zones; small, well rounded, reddish, chert, coarse sand grains throughout.

Samples collected:

| | | |
|---|---|---|
| 101109 | HU-1 | 4' 0" to 8' 0" |
| 101110 | HU-2A | 8' 0" to 12' 0" |
| 101111 | HU-2B | 12' 0" to 16' 0" |
| 101112 | HU-3B | 16' 0" to 21'0" |
| 101113 | HU-3 | 21' 0" to 24' 0" |

Notes:
HU-1 is dominated by Peorian aged loess, but an older loess is identified at the base of the unit. The order loess had strongly contrasting mottling and higher clay content. However, the higher clay content may be largely due to clay flows.
HU-2 is identified as alluvium by the presence of chert fragments. This section of the core has a high silt content although one sandy strata was identified.
HU-3 is identified by the very firm and stiff consistency and by the strongly contrasting mottle pattern. This is not a strong positive identification however.

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**CORE 194-05**

The drill rig was moved farther west on West Boone Road to the approximate location specified by the grid coordinates. The drill rig was about 100 feet south off the road and at the edge of a field. Large trees in a fence row were near by.

Core Description

0' 0" to 0' 7" Ap Horizon; removed by the driller to put coring tube into the ground.

0' 7" to 1' 0" Ap Horizon; brown (10YR 4/3) silt loam.

1' 0" to 3' 3" Bw or Bt Horizon; yellowish brown (10YR 5/4) silt loam.

3' 3" to 5' 0" Bt1 Horizon; yellowish brown (10YR 5/4) silt loam; light brownish gray (10YR 6/2) coatings and depleted areas on tops and sides of prisms; roots to about 5 feet.

5' 0" to 6' 6" Bt2 Horizon; dark yellowish brown (10YR 4/4) silt loam with light gray (10YR 7/1) and light brownish gray (10YR 6/2) coatings on prism faces; thin black Mn coatings on some prism faces; near 6 feet, the prisms either end or smaller prisms disappear into larger prisms.

6' 6" to 7' 0" Dark yellowish brown (10YR 4/4) silt loam with light brownish gray flow zones; no Mn or Fe nodules. Base of younger loess deposit.

7' 0" to 8' 0" Yellowish brown (10YR 5/4) silt loam with common, hard, black, Mn nodules 1-3 mm in diameter.

8' 0" to 8' 9" Missing section.

8' 9" to 10' 9" Dark yellowish brown (10YR 4/4) silt loam. Common, hard, black, Mn nodules and some black coatings on vertical cracks.

| | |
|---|---|
| 10' 9" to 11' 7" | Dark yellowish brown (10YR 4/4) silt loam in the upper part becoming yellowish brown (10YR 5/6) in the lower part; many large 0.5 to 10 mm diameter Mn nodules that have small hard centers 2-3 mm in diameter. Zone of manganese concentration. BASE OF LOESS. BASE OF HU-1. |
| 11' 7" to 12' 0" | Paleo A Horizon? Olive yellow (2.5Y 6/6) silty clay loam with strong brown (7.5YR 4/6) Fe-Mn nodules; brown (10YR 4/3) clay plugged areas. |
| 12' 0" to 14' 3" | Paleosol Bt1 Horizon; yellowish brown (10YR 5/4) clay or silty clay with grayish brown (10YR 5/2) depletions and dark brownish gray (10YR 4/2) clay flows; few black nodules; faint yellowish brown (10YR 5/6) diffuse areas of higher oxidation; no pebbles and no geologic stratification. |
| 14' 3" to 15' 6" | Paleosol Bt2 Horizon; brown (10YR 5/3) and yellowish brown (10YR 5/6) clay with a few pebbles; light brownish gray (10YR 6/2) depleted vertical flow zones and grayish brown (10YR 5/2) clay flows. |
| 15' 6" to 16' 3" | Brown (10YR 5/3) and yellowish brown (10YR 5/6) very gravelly clay; grayish brown (10YR 5/2) clay flows and light brownish gray (10YR 6/2) depleted areas in flow zones; few dark red (2.5YR 3/6) soft Fe nodules. BASE OF HU-2. |
| 16' 3" to 18' 0" | Paleosol Btg1 Horizon in the top of the Porters Creek Section. Light gray (10YR 6/1) and light brownish gray (10YR 6/2) clay with dark red (2.5YR 3/6) oxidized zones; few lag gravel; gray (10YR 5/1) clay flows. |
| 18' 0" to 19' 6" | Paleosol Btg2 Horizon; gray (10YR 6/1) clay with a great decrease in dark red (2.5YR 3/6) oxide accumulations and an increase in yellowish brown (10YR 5/6) Fe accumulations. There is no geologic stratification in these two paleosol Btg horizons. |
| 19' 6" to 20' 3" | Paleosol B&C Horizon; B part is light olive brown (2.5Y 5/6) clay without pebbles; C horizon pieces are grayish brown (10YR 5/2). Geologic stratification becomes very evident at the base of this horizon. |
| 20' 3" to 21' 0" | Grayish brown (2.5Y 5/2) clay with thin, mostly horizontal yellowish brown (10YR 5/6) oxide zones 1-2mm wide with dark yellowish brown (10YR 4/6) centers that are very firm. |
| 21' 0" to 22' 0" | Glauconitic zone; grayish brown (2.5Y 5/2) clay or silty clay with abundant dark green pellets; yellow (5Y 7/6) jarosite zones 1-3 mm wide and dark yellowish brown (10YR 4/6) hard Fe oxides accumulations along cracks. One jarosite band occurs at the base of this section. |
| 22' 0" to 24' 0" | Dark gray (10YR 4/1) clay with strong brown (7.5YR 5/6) oxidized zones and crack fillings of Fe oxides; very thin olive yellow (2.5Y 6/6) jarosite filed crack less than 1mm thick; few light brownish gray (2.5Y 6/2) flow zones along tight cracks; wider cracks and flow zones have thick Fe oxide accumulations. |
| 24' 0" to 27' 0" | Grayish brown (10YR 5/2) and dark grayish brown (10YR 4/2) clay with brownish yellow (10YR 6/8) oxidized zones 2-5 mm wide and strata of grayish brown (2.5Y 5/2). |
| 27' 0" to 27' 7" | Dark brown (7.5YR 4/4) silty clay or silty clay loam. Weathered out glauconitic strata. |
| 27' 7" to 27' 9" | Grayish brown (10YR 5/2) clay with light yellowish brown (10YR 6/4) and brownish yellow (10YR 6/8) oxidized zones; very thin olive yellow (2.5Y 6/6) jarosite coating on a crack face at the base of this section. |
| 27' 9" to 28' 5" | Dark gray (10YR 4/1) clay. A large crack runs diagonally through that has a brownish yellow (10YR 6/6) oxidized zone and dark brown (7.5YR 4/4) Fe oxide accumulations. |
| 28' 5" to 28' 7" | Brown (10YR 4/3) clay with thin yellowish brown (10YR 5/6) strata. |

Samples collected:

Notes:
HU-1 seems to consist of loessal deposits of two ages based on the presence of nodules in the older lower loess.
HU-2 has a paleosol that goes entirely through the section. HU-2 is interpreted to be alluvium based on the presence of chert gravels.

The Porters Creek Clay contains pyritic materials and this particular section has undergone acid sulfate weathering processes. The Porters Creek was at the surface at one time where wetland soil genesis formed the preserved paleosol. Most of the pyritic materials have been oxidized resulting in the rather thick iron oxide accumulations. However, primarily associated with glauconitic strata, the presence of jarosite implies that acid sulfate weathering is still occurring even though the upper Porters Creek clay has been fairly well oxidized and leached.

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**CORE 194-06**

Core 194-06 is located within 24 inches of core 194-05.

Core Description

0' 0" to 0' 6" Ap Horizon. This section was removed in order to get the first coring tube in the ground.

0' 6" to 1' 0" Ap Horizon; brown (10YR 4/3) silt loam.

1' 0" to 1' 11" Bw Horizon; yellowish brown (10YR 5/4) silt loam.

1' 11" to 3' 3" Bt Horizon; dark yellowish brown (10YR 4/6) silty clay loam; prismatic soil structure with light brownish gray (10YR 6/2) depletions along prism faces; some dark brown (7.5YR 4/4) Fe accumulations.

3' 3" to 4' 2" C1 Horizon; light brownish gray (10YR 6/2) silt loam with dark yellowish brown (10YR 3/4) Mn accumulations.

4' 2" to 6' 0" C2 Horizon; dark yellowish brown (10YR 4/6) silt loam with large light brownish gray (10YR 6/2) depletions and grayish brown (10YR 5/2) clay flows; black Mn coatings on some flow faces.

6' 0" to 7' 0" C3 Horizon; dark yellowish brown (10YR 4/6) silt loam with light brownish gray (10YR 6/2) flow zones.

7' 0" to 9' 0" C4 Horizon; dark yellowish brown (10YR 4/4) silt loam; common hard Mn nodules; pale brown (10YR 6/3) flow zone depletions.

9' 0" to 10' 3" C5 Horizon; yellowish brown (10YR 5/4) silt loam with thin light brownish gray (10YR 6/2) flow zones.

10' 3" to 11' 3" Yellowish brown (10YR 5/4) silt loam with many 3-10 mm Mn concentrations having a hard center nodule 1-2mm in size. Many large Mn accumulations also have a rind of dark yellowish brown (10YR 4/6) Fe oxide accumulation. BASE OF LOESS AND HU-1.

11' 3" to 14' 0" Paleosol Bt Horizon; yellowish brown (10YR 5/4) clay; no sand grain size coarser than very fine sand; no pebbles; yellowish red (5YR 5/8) Fe coatings on ped faces; small 1mm black Mn soft accumulations; thick reddish brown (5YR 5/3) clay flows; few to common 1-2mm thick Fe-Mn nodules; thin light brownish gray (10YR 6/2) flow zones.

14' 0" to 15' 0" Yellowish brown (10YR 5/4) gravelly clay; light brownish gray (10YR 6/2) flow zones and grayish brown (10YR 5/2) clay flows.

15' 0" to 17' 3" Pale brown (10YR 6/3) gravelly to very gravelly clay; yellowish brown (10YR 5/6) Fe accumulations and red (2.5YR 4/6) Fe oxide high contrast accumulations that are soft; light brownish gray (10YR 5/2) clay flows that are 1-2mm thick. BASE OF CONTINENTAL DEPOSITS AND BASE OF HU-3. (HU-2 is missing?)

| | |
|---|---|
| 17' 3" to 17' 9" | Lag gravel at the top of the porters Creek Clay; brown (7.5YR 5/2) very gravelly to extremely gravelly clay; few strong brown (7.5YR 5/6) Fe accumulations; gray (10YR 5/1) clay flows and a few yellowish brown (10YR 5/4) oxidized areas. |
| 17' 9" to 20' 3" | Paleosol Btg Horizon in Porters Creek Clay; light brownish gray (10YR 6/2) clay with a few lag gravels; gray (10YR 6/1) and grayish brown (10YR 5/2) clay flows; thick coatings of dark brown (7.5YR 3/3) clay in cracks along with strong brown (7.5YR 5/8) Fe accumulations at the base of this section. |
| 20' 3" to 21' 0" | Oxidized C Horizon of Paleosol; brown (7.5YR 4/2) clay; very high clay content; strong brown (7.5YR 5/8) Fe oxidized zones 2-5mm wide; yellowish red (5YR 4/6) firm to very firm oxide accumulations 2-3mm thick on fracture and crack faces. |
| 21' 0" to 22' 0" | Brown (7.5YR 5/2) clay with abundant dark green to black glauconite pellets. |
| 22' 0" to 24' 3" | Brown (7.5YR 4/2) clay; strong brown (7.5YR 5/8) oxidized zones along cracks; yellowish red (5YR 4/6) Fe oxide accumulations in cracks that are very firm. |
| 24' 3" to 28' 0" | 40% brown (7.5YR 5.2) and 40% strong brown (7.5YR 5/8) oxidized zones with clay texture; red (2.5YR 4/8) Fe accumulations on vertical crack faces and yellowish red (5YR 4/6) Fe accumulations on horizontal and inclined crack faces. |

Samples collected:

| | | |
|---|---|---|
| 101130 | HU-1 | 4' 0" to 11' 0" |
| 101131 | HU-3 | 11' 0" to 17' 3" |
| 101132 | Paleo Bt of Porters Creek | 17' 3" to 20' 3" |
| 101133 | Porters Creek glauconitic section | 21' 0" to 22' 0" |
| 101134 | Porters Creek | 20' 0" to 21' 0", 22' 0" to 24' 0" and 24' 0" to 28' 0" |

Notes:

HU-1 is very thick. More than one age sequence may be present.
HU-2 is missing.
HU-3 section contains a fairly well oxidized paleosol. Evidence for soil genesis is that the geologic stratification has been erased by the formation of soil structure and the presence of numerous clay flows.

The Porters Creek Clay has undergone acid sulfate weathering. It is amazing that this core and 194-05 are so much different when they are so close together. The Porters Creek also contains a Paleosol.

**DRILLING AREA NEAR MONITORING WELL # 196.**

Drill sites 196-01 and 196-02 are located close to the grid intersections specified on page 29 of The Plan. These drill sites, located about 100 feet south of South Acid Road on a stable landform, are less than 24 inches apart.

Core Description

0' 0" to 0' 6" Ap Horizon; brown (10YR 4/3) silt loam with many grass roots.

0' 6" to 2' 3" Bt1 Horizon; brown (10YR 4/3) silty clay loam with few to common roots.

2' 3" to 4' 0" Bt2 Horizon, top of prismatic soil structure; dark yellowish brown (10YR 4/4) silty clay loam prism interiors; pale brown (10YR 6/3) prism exterior coatings and tonguing between prisms.

4' 0" to 6' 0" C Horizon; dark yellowish brown (10YR 4/6) silt loam with prismatic structure; light brownish gray (10YR 6/2) vertical water flow zones around prisms; soft Mn accumulations at 6 feet. BASE OF PEORIAN LOESS.

6' 0" to 7' 0" Strong brown (7.5YR 4/6) silty clay loam; few pinkish gray (7.5YR 6/2) clay flows. ROXANNA LOESS? ABRUPT BOUNDARY TO HU-2 BENEATH.

7' 0" to 9' 0" Dark brown (7.5YR 4/4) loam with few chert gravels; light gray (10YR 6/1) depleted water flow zones.

9' 0" to 10' 9" Reddish brown (5YR 4/4) gravelly loam or gravelly clay loam. BASE OF HU-2.

10' 9" to 12' 0" Erosional surface with lag gravels; reddish brown (5YR 4/4) coarse sandy loam or coarse loamy sand with a few rounded pebbles; pockets of reddish brown 5YR 5/4) loamy sand and irregular areas of pinkish gray 5YR 7/2) clean uncoated sand grains.

12' 0" to 14' 0" Red (2.5YR 4/6) sandy loam with strata of red (10R 4/6) sandy clay loam; no gravels; yellowish brown (10YR 5/6) flow zones slightly depleted in clay and Fe oxides.

14' 0" to 14' 3" Gray (10YR 5/1) sandy clay within a larger area of yellowish brown (10YR 5/8) sandy loam on either side.

14' 3" to 15' 0" Red (10R 4/6) sandy loam or sandy clay loam and red (2.5YR 4/6) loamy sand strata. BOTTOM OF CORE.

Samples collected:

| | | |
|---|---|---|
| 101116 | HU-1 | 4' 0" to 7' 0" |
| 101117 | HU-2 | 7' 0" to 10' 9" |
| 101118 | Eocene sands | 12' 0" to 15' 0 (Clay strata not sampled) |

**CORE 196-02**

This core was collected 12 to 24 inches away from Core 196-01.

Core Description

0' 0" to 0' 6" Ap Horizon; brown (10YR 4/3) silt loam.

0' 6" to 1' 11" Bt1 Horizon; yellowish brown (10YR 5/6) silty clay loam; dark yellowish brown (10YR 4/4) clay films; roots; subangular blocky soil structure.

1' 11" to 3' 0" Bt2 Horizon; dark yellowish brown (10YR 4/4) light silty clay loam; brown (10YR 5/3) and pale brown (10YR 6/3) prism faces and depleted flow zones; soft diffuse black Mn accumulations.

3' 0" to 4' 0" Bt3 or BC Horizon; dark yellowish brown (10YR 4/4) silt loam; light brownish gray (10YR 6/2) and light gray (10YR 7/1) flow zones and perched water zones; strong brown (7.5YR 4/4) clay flows in large pores with black Mn films coating surfaces of clay films; much root and faunal activity to a depth of about 4 feet.

4' 0" to 6' 0" C Horizon; dark yellowish brown (10YR 4/6) silt loam with pale brown (10YR 6/3 partially depleted flow zones. BASE OF PEORIAN LOESS.

6' 0" to 7' 0" Strong brown (7.5YR 4/4) silty clay loam; very prominent white (10YR 8/1) flow zones; 2-3mm soft Mn nodules and a few hard Mn nodules. ROXANNA LOESS? BASE OF HU-1.

7' 0" to 9' 0" Strong brown (7.5YR 4/4) loam and thin strata of silt loam with common to many chert gravels; few pinkish gray (7.5YR 6/2) flow zones 1-2mm wide.

9' 0" to 10' 6" Dark Brown (7.5YR 4/4) very gravelly loam with high silt content. BASE OF HU-2.

10' 6" to 11' 6" Transition zone between HU-2 and Eocene Sands; red (10YR 4/6) very gravelly sandy loam or very gravelly sandy clay loam mixed with dark brown (7.5YR 4/4) very gravelly silty clay loam.

11' 6" to 14' 0" Red (10R 4/6) stratified coarse sandy loam, coarse sandy clay loam and red (2.5YR 4/6) coarse loamy sand.

14' 0" to 14' 3" Pinkish gray (7.5YR 6/2) and light gray (10YR 6/1) clay strata surrounded by strong brown (7.5YR 5/7) and yellowish brown (10YR 5/6) rinds.

14' 3" to 14' 6" Red (10R 4/6) coarse sandy loam. END OF CORE.

14' 6" to 30' 3" Augered down through Eocene sands. Hit perched water about 29 feet in a clean sand strata. AUGERED JUST INTO CLAY STRATA.

30' 3" to 32' 6" White (10YR 8/1) clay or silty clay with yellowish brown (10YR 5/6-5/8) Fe accumulations along bedding planes. THIS SAMPLE OBTAINED BY GEO-PROBE CORING.

32' 6" to 33' 6" Stratified red (2.5YR 4/6) loamy sand, strong brown (7.5YR 4/6) and very pale brown (10YR 7/4) sand or loamy sand. DRILLING AND PROBE CORING TERMINATED.

Samples collected:

| | | |
|---|---|---|
| 101119 | HU-1 | 4' 0" to 7' 0" |
| 101120 | HU-2 | 7' 0" to 10' 6" |
| 101121 | Eocene sands | 11' 6" to 14' 6". (Clayey strata not sampled) |
| 101122 | Eocene clay strata | 30' 6" to 32' 6" |

Notes:
HU-1 consists of Peorian Loess and some Roxanna Loess.
HU-2 is alluvium that becomes coarser with depth.
The upper part of the Eocene sands is highly oxidized and has a typical red color.

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**CORE 196-03**

The Geo-Probe rig moved about 400-500 feet north of drill site 196-02 and lower down the slope. The idea for moving in this direction was to have less Eocene sand to go through to reach the Porters Creek Clay. However, this turned out not to be what happened.

Core Description

0' 0" to 0' 6" Ap Horizon; brown (10YR 4/3) silt loam.

0' 6" to 0' 8" E. Horizon; pale Brown (10YR 6/3) silt loam.

0' 8" to 1' 3" Btg1 Horizon; light brownish gray (10YR 6/2) silt loam.

1' 3" to 2' 6" Btg2 Horizon; light gray (10YR 6/1) silty clay loam with small black Mn bodies and threads of yellowish brown (10YR 5/4) Fe accumulations in the upper part becoming more numerous in the lower part.

2' 6" to 5' 6" C1 Horizon; yellowish brown (10YR 5/4) silt loam with grayish brown (10YR 5/2) depleted areas; roots to 48 inches; dark yellowish brown (10YR 4/6) areas of Fe accumulations; dark gray clay (10YR 4/1) plug in the bottom of a krotovina.

5' 6" to 6' 7" C2 Horizon; light olive brown (2.5Y 5/4) silt loam with small black Mn bodies; grayish brown (10YR 5/2) flow zones surrounded by strong brown (7.5YR 4/6) Fe accumulations. BASE OF LOESS AND HU-1.

6' 7" to 8' 6" Light olive brown (2.5Y 5/4) loam with black accumulations and threads associated with light gray (10YR 7/2) depleted flow zone areas.

8' 6" to 10' 0" Mottled light olive brown (2.5Y 5/3), light brownish gray (10YR 6/2), and dark yellowish brown (10YR 4/6) loam.

10' 0" to 12' 9" Saturated zone, not able to describe colors; texture is loam; BASE OF HU-2.

12' 9" to 13' 9" Highly mottled yellowish brown (10YR 5/4), dark yellowish brown (10YR 4/6), and light brownish gray (10YR 6/2) firm and stiff sandy clay loam with soft pebbles weathered enough to cut through.

13' 9" to 15' 0" Light gray (10YR 7/1) sandy clay loam with yellowish brown (10YR 5/6) Fe accumulations and light gray (10YR 6/1) clay flows.

15' 0" to 15' 3" White (10YR 8/1) and light gray (10YR 7/1) clay with well rounded coarse sand particles.

15' 3" to 15' 9" Light gray (10YR 7/2) sandy loam or sandy clay loam with light brownish gray (10YR 6/2) slightly oxidized zones.

15' 9" to 16' 6" Saturated zone; light yellowish brown (2.5Y 6/3) and light gray (10YR 7/1) sandy loam dominated by medium sand.

16' 6" to 17' 0" Light gray (N7/) and light yellowish brown (2.5Y 6/3) sandy loam.

17' 0" to 17' 6" White (10YR 8/1) clay or silty clay with a few sand grains.

17' 6" to 21' 0" Light yellowish brown (10YR 6/4) coarse loamy sand and strata of yellow (2.5Y 7/6) coarse loamy sand or coarse sandy loam; strong brown (7.5YR 4/6) vertical zones about 1 cm in diameter. BASE OF CORE.

Samples collected:

| | | |
|---|---|---|
| 101123 | HU-1 | 2' 6" to 6' 6" |
| 101124 | HU-2 | 7' 0" to 10' 6" |
| 101125 | Eocene Sands | 18' 0" to 21' 0" |

Notes:
HU-1 is Peorian Loess. There is an abrupt transition at the base of the HU-1.
HU-2 is mostly deoxidized and depleted in both manganese and iron oxides.
The Eocene Sands are highly deoxidized and highly depleted in iron oxides.

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**CORE 196-04**

The Geo-probe rig was moved about 300 feet west and 100 feet north of drill site 196-01.

Core Description

Rounded oxide coated chert pebbles were scattered about on the ground surface, but none were in the loess beneath. How the gravel came to be on the surface is not known.

0' 0" to 0' 6" Ap Horizon; removed by digging deep enough to start the coring tube.

0' 6" to 2' 3" Missing interval.

2' 3" to 3' 0" Bt Horizon; dark yellowish brown (10YR 4/6) silty clay loam. Subangular blocky soil structure.

3' 0" to 4' 0" Bt Horizon; strong brown (7.5YR 4/6) silty clay loam prism interiors and light gray (10YR 7/2) prism exteriors.

4' 0" to 4' 9" C Horizon; brown (7.5YR 5/4) silt loam. BASE OF PEORIAN LOESS.

4' 9" to 6' 9" Strong brown (7.5YR 4/4) silty clay loam with light brownish gray (10YR 6/2) flow zones. BASE OF ROXANNA LOESS. BASE OF HU-1.

6' 9" to 8' 0" Brown (7.5YR 5/4) loam with a few chert pebbles; many pores and vesicles filled with brown (7.5YR 4/4) clay; brown (7.5YR 5/3) flow zones.

8' 0" to 9' 0" Stratified brown (7.5YR 5/3) sandy loam with strong brown (7.5YR 4/6) loam or clay loam; few rounded pebbles; yellowish red (5YR 5/8) Fe accumulations.

9' 0" to 10' 3" Brown (7.5YR 5/4) very gravelly loam or very gravelly sandy loam; hard, coated chert gravels. BASE OF HU-2.

10' 0" to 10' 3" Weathered lag gravels imbedded in the top of red Eocene sand.

10' 3" to 12' 3" PALEO Bt HORIZON; red (2.5YR 4/6) clay with sand grains; red (2.5YR 4/8) clay flows; dark reddish brown (5YR 3/4) clay in pores and vesicles; red (10R 4/6) and brownish yellow (10YR 6/6) contrasting mottles; yellowish red (5YR 4/6) partially deoxidized flow zones. Geologic stratification destroyed and no longer evident.

12' 3" to 12' 6" Pale yellow (2.5Y 7/3) clay.

12' 6" to 12' 9" Red (10R 4/6) sandy loam or sandy clay loam with thin 2-3mm thick strata of pale yellow (2.5Y 7/3) clay.

12' 9" to 13' 3" Light gray (2.5Y 7/2) clay strata separated by red (10R 4/6) sandy loam or sandy clay loam strata that are 0.5mm to 10 mm thick.

13' 3" to 13' 7" Red (2.5YR 4/6) sandy clay loam or sandy clay with thin 2-5mm thick light gray (2.5Y 7/2) clay strata.

13' 7" to 14' 0" Light gray (2.5Y 7/2) clay strata 0.5 to 10 mm thick separated by thinner 2-3mm strata of red (10R 4/6) sandy clay loam.

14' 0" to 19' 6" Highly stratified red (2.5YR 5/6) red (2.5YR 4/6) and yellowish red (5YR 4/6) sandy loam and sandy clay loam with white (10YR 8/1) weathered-out feldspar coarse sand sized grains; redder strata have lower clay conten; individual strata are 2-3 mm thick. A large paleo-krotovina was in the core at a depth of 16l1î to 17l9î. This feature was filled with sticky strong brown (7.5YR 4/6) clay. Immediately surrounding the clay filled center is a rind of brownish yellow (10YR 6/6) deoxidized material. The entire krotovina is set in a red (2.5YR 4/6) matrix.

19' 6" to 22' 0" Pale yellow (2.5Y 7/3) and light gray (2.5Y 7/2) sandy loam; ddominant sand particle size is medium sand but there is some fine sand; white (10YR 8/1) loamy sand or sandy loam flow zones 1-2 cm thick and thin strata of dark red (2.5YR 3/6) sandy clay loam. Stratification is very evident.

22' 0" to 23' 6" Reddish yellow (7.5YR 6/6) sandy loam, saturated with water.

23' 6" to 25' 0" White (10YR 8/1) loamy sand; saturated; black threads about 2 mm wide associated with diffuse very pale brown (10YR 8/3) and light brownish gray (10YR 6/2) areas.

25' 0" to 26' 0" White (10YR 8/2) clean sand, saturated. BASE OF CORE.

26' 0" to 41' 6" Drilling interval. Drill hit clay strata at 41'6". The augers were removed and a probe inserted to try to obtain a core of the clay. The coring tube penetrated the clay and went back into sand. There was no core recovery of clay. A second core was attempted below a depth of 43 feet, but only sand was recovered. The clay strata was approximately 2 feet thick and the conclusion, later, was that it was a strata in the lower Eocene and not the Porters Creek clay as had been the initial interpretation. The field logbook entries were changed to reflect this interpretation.

Samples collected:

| | | |
|---|---|---|
| 101126 | HU-1 | 4' 0" to 6' 8". |
| 101127 | HU-2 | 6' 8" to 10' 0" |
| 101128 | Eocene-A | 14' 0" to 16' 0" and 17' 6" to 20' 0". |
| 101129 | Eocene-B | 23' 6" to 26' 0". |

Notes:
HU-1 is Peorian loess in spite of the pebbles on the surface. The Roxanna loess was thicker here than in drill cores 196-01 and 196-02.
HU-2 is interpreted to be alluvium of continental origins. There appears to be a truncated paleo argillic horizon at the top of this section based on the lack of any stratification.
A paleo argillic horizon was positively identified at the top of the Eocene section. The upper Eocene paleosol is well oxidized, but the strata beneath become more deoxidized with increasing depth. The paleo krotovina occurs at a slight single. The lower end is truncated by the core edge.

## FIELD SAMPLING PROCEDURES OF DEEP CORING PHASE

1. The drill site is located as close as possible to the grid coordinates in advance of the driller.
2. Drillers arrive at the site and set up the rig.
3. Drillers use their cleaned and rinsed coring tubes and place new acetate sleeves in them and a cleaned core tip is screwed on the end to seal the coring tube.
4. The first coring tube is pushed and hammered into the soil to the full 4' depth of the tube. However, because of the low soil bulk density near the surface, the core tube is never full of sample due to compaction and the tube pushing soft soil out of the away as it is driven into the soil.
5. The second coring tube 4'0" to 8'0" is pushed or hammered down to the prescribed depth. A small clean rod, inserted down the center of the drill rod, is used to unscrew the sealed core tip. The coring tube is then pushed and hammered to the next prescribed depth and then retrieved. This step is repeated to reach any depth required. Maximum depth using this particular "Geo Probe" rig is about 20' to 24' depending on the properties of the soil. If part of a core is lost, it is not recovered in the next lower coring tube.
6. When the coring tube is back at the surface it is placed in a vise and the top and bottom fixtures removed. The core contained in the acetate sleeve is removed, the coring tip removed by either shaking the tube or using a hacksaw to cut off that part of the sleeve where the core tip is located. Both ends of the acetate sleeve are capped, the core section identified and the depth written on the outside, and which end is down. This procedure is repeated, with depth variations until the desired depth has been achieved or the drill rig can penetrate no deeper.
7. Before a full set of cores is laid out on a table, the outside of each sleeve is thoroughly cleaned of any soil contamination by repeated wiping of the sleeve with clean paper towels. Each tube is then laid on a sheet of aluminum foil. An estimate is made of where important soil geologic strata changes occur in each tube.
8. A clean utility knife is used to cut each tube into half. The top half is lifted off and placed next to the exposed core. This is done for each tube. The utility knife is cleaned each time as a geologic change occurs. At this time a background rad scan and VOCs scan is performed on the entire core. The background is recorded in the field logbook.
9. A careful examination of the entire core is done using cleaned and rinsed stainless steel spatulas to accurately determine where important geologic/soils changes occur that will determine sample collection.
10. A cleaned and rinsed spatula is used to remove part of the core. This material is placed in the top half of the sleeve and used to describe the core. Clean spatulas are used wherever important changes occur.
11. Using gloves and clean spatulas, samples are placed into one liter plastic bottles. Because of the small diameter of the core, a nearly complete geologic section is placed into one or more jars in order to have enough sample. Multiple jars needed to contain one part of the core are labeled the same except where separate upper, middle and lower subsamples are collected. These subsamples of a particular geologic section are labeled "A," "B," and "C" and noted in the field logbook under the heading (samples collected).
12. Where cores are collected in and below a perched water table the outer core is covered with mud. After the thoroughly cleaned and rinsed acetate sleeve has been slit open, the core is carefully lifted out and carefully sprayed with distilled water to remove the attached mud. If necessary, the surface of the core is scraped deep enough to remove embedded sand grains. The final cleaning will be done in the soil prep lab after the core has been allowed to partially dry.
13. University of Kentucky personnel are also sampling for metal analyses. Their procedure is to collect small subsamples along the entire length of each geologic section so that they will obtain a field composite that should have similar properties as the soil prep lab composited samples.
14. Bottles filled with samples are labeled and checked with field logbook entries. Samples are placed in the cardboard box and kept in a locked van. All samples from the deep coring phase of this project are transported in the van back to ORNL and placed in a secure locked soil prep lab.
15. The last core collected on Sunday, August 11, was transported intact back to ORNL. On Monday, August 12, this core was handled in the same manner as outlined in the steps above.

# APPENDIX C

# COMPOSITE SAMPLE DESCRIPTION

**Sample Description and Site Locations for Composite Sample Numbers**

| Composite Sample Number | Sample Description | Site Location[a] | Composite Sample Number | Sample Description | Site Location[a] |
|---|---|---|---|---|---|
| 301001 | Falaya A | F 12,20,22 | 301029 | Henry A | H 03,07,13 |
| 301002 | Falaya A | F 12,20,22 | 301030 | Henry B | H 03,07,13 |
| 301003 | Falaya B | F 12,20,22 | 301036 | HU-1 | 194-03,194-04 |
| 301004 | Falaya B | F 12,20,22 | 301037 | HU-1 | 196-01,196-02 |
| 301005 | Falaya A | F 04,02,29 | 301038 | HU-1 | 196-03,196-04 |
| 301006 | Falaya B | F 04,02,29 | 301039 | HU-1 | 194-05,194-06 |
| 301007 | Falaya A | F 05,07,17 | 301040 | HU-1L | 194-01,194-02 |
| 301008 | Falaya B | F 05,07,17 | 301041 | HU-1L | 194-03,194-04 |
| 301009 | Falaya A | F 01,21,23 | 301042 | HU-1L | 194-05,194-06 |
| 301010 | Falaya B | F 01,21,23 | 301043 | HU-2 | 194-01,194-02 |
| 301011 | Calloway A | C 12,18,19 | 301044 | HU-2 | 194-01,194-02 |
| 301012 | Calloway B | C 12,18,19 | 301045 | HU-2 | 194-03,194-04 |
| 301013 | Calloway A | C 07,08,09 | 301046 | HU-2 | 194-03,194-04 |
| 301014 | Calloway B | C 07,08,09 | 301047 | HU-3 | 194-01,194-02 |
| 301015 | Calloway A | C 07,08,09 | 301048 | HU-3 | 194-01,194-02 |
| 301016 | Calloway B | C 07,08,09 | 301049 | HU-3 | 194-04 |
| 301017 | Calloway A | C 01,10,24 | 301050 | HU-3 | 194-05,194-06 |
| 301018 | Calloway B | C 01,10,24 | 301051 | HU-1L | 194-03,194-04 |
| 301019 | Calloway A | C 02,03,20 | 301052 | HU-2 | 196-03,196-04 |
| 301020 | Calloway B | C 02,03,20 | 301053 | Eocene Sand | 196-01,196-02 |
| 301021 | Henry A | H 04,06,09 | 301054 | Eocene Sand | 196-04 |
| 301022 | Henry B | H 04,06,09 | 301055 | Eocene Sand | 196-03 |
| 301023 | Henry A | H 04,06,09 | 301056 | Eocene Sand | 196-04 |
| 301024 | Henry B | H 04,06,09 | 301057 | P.C. Clay | 194-05,194-06 |
| 301025 | Henry A | H 01,05,15 | 301058 | P.C. Clay | 194-05,194-06 |
| 301026 | Henry B | H 01,05,15 | 301059 | P.C. Clay | 194-06 |
| 301027 | Henry A | H 02,10,18 | 301060 | P.C. Clay | 194-05 |
| 301028 | Henry B | H 02,10,18 | 301061 | Eocene Clay | 196-02 |

[a]See Appendix B for site coordinates and location on site map.

# APPENDIX D

# DATA PACKAGE PRINTOUT FROM PGDP

# Data Package Printout from PGDP

**Note, geochemical data beyond those included in the following data summary were collected during the investigation (e.g., pH, sand content, etc.). Although these data are not presented here, they are in the environmental database maintained by the Paducah Gaseous Diffusion Plant Environmental Restoration Program.**

# Background Soils Project Analytical Data

3/10/97

## Location 194-01,02

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301040 | ALPHA | LAL | Thorium-228 | 950 | | pCi/Kg | 150 |
| 301040 | ALPHA | LAL | Thorium-230 | 890 | | pCi/Kg | 140 |
| 301040 | ALPHA | LAL | Thorium-232 | 940 | | pCi/Kg | 140 |
| 301040 | ALPHA | LAL | Uranium-233/234 | 750 | | pCi/Kg | 110 |
| 301040 | ALPHA | LAL | Uranium-235 | 53 | | pCi/Kg | 30 |
| 301040 | ALPHA | LAL | Uranium-238 | 790 | | pCi/Kg | 120 |
| 301040 | BETA | LAL | Technetium-99 | 260 | | pCi/Kg | 210 |
| 301040 | GAMMA | LAL | Actinium-228 | 890 | | pCi/Kg | |
| 301040 | GAMMA | LAL | Bismuth-212 | 480 | | pCi/Kg | |
| 301040 | GAMMA | LAL | Bismuth-214 | 803 | | pCi/Kg | |
| 301040 | GAMMA | LAL | Cesium-137 | -5 | | pCi/Kg | 11 |
| 301040 | GAMMA | LAL | Cobalt 60 | -5.3 | | pCi/Kg | |
| 301040 | GAMMA | LAL | Lead-210 | 1200 | | pCi/Kg | |
| 301040 | GAMMA | LAL | Lead-212 | 806 | | pCi/Kg | |
| 301040 | GAMMA | LAL | Lead-214 | 943 | | pCi/Kg | |
| 301040 | GAMMA | LAL | Potassium-40 | 9700 | | pCi/Kg | 1100 |
| 301040 | GAMMA | LAL | Radium-223 | -130 | | pCi/Kg | |
| 301040 | GAMMA | LAL | Thallium-208 | 282 | | pCi/Kg | |
| 301040 | GAMMA | LAL | Thorium-234 | 970 | | pCi/Kg | 350 |
| 301040 | GAMMA | LAL | Uranium-235 | 50 | | pCi/Kg | 110 |
| 301040 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg | |
| 301040 | ICP-MS | LAL | Beryllium | 0.23 | B | mg/Kg | |
| 301040 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301040 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301040 | ICP-MS | LAL | Thorium-232 | 4.8 | | mg/Kg | |
| 301040 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301040 | ICP-MS | LAL | Uranium-238 | 0.72 | | mg/Kg | |
| 301040 | NAA | ORN | Thorium-232 | 7.6 | | mg/Kg | |
| 301040 | NAA | ORN | Uranium-235 | 0.02 | | mg/Kg | |
| 301040 | NAA | ORN | Uranium-238 | 3 | | mg/Kg | |
| 301040 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 7.28 | | % | |
| 301043 | ALPHA | LAL | Thorium-228 | 910 | | pCi/Kg | 140 |
| 301043 | ALPHA | LAL | Thorium-230 | 710 | | pCi/Kg | 110 |
| 301043 | ALPHA | LAL | Thorium-232 | 850 | | pCi/Kg | 120 |
| 301043 | ALPHA | LAL | Uranium-233/234 | 513 | | pCi/Kg | 92 |
| 301043 | ALPHA | LAL | Uranium-235 | 48 | | pCi/Kg | 28 |
| 301043 | ALPHA | LAL | Uranium-238 | 596 | | pCi/Kg | 99 |
| 301043 | BETA | LAL | Technetium-99 | -10 | | pCi/Kg | 200 |
| 301043 | GAMMA | LAL | Actinium-228 | 672 | | pCi/Kg | |
| 301043 | GAMMA | LAL | Bismuth-212 | 420 | | pCi/Kg | |
| 301043 | GAMMA | LAL | Bismuth-214 | 544 | | pCi/Kg | |
| 301043 | GAMMA | LAL | Cesium-137 | -8 | | pCi/Kg | 11 |
| 301043 | GAMMA | LAL | Cobalt 60 | -2.8 | | pCi/Kg | |
| 301043 | GAMMA | LAL | Lead-210 | 20000 | | pCi/Kg | |
| 301043 | GAMMA | LAL | Lead-212 | 644 | | pCi/Kg | |
| 301043 | GAMMA | LAL | Lead-214 | 702 | | pCi/Kg | |

# Background Soils Project Analytical Data

3/10/97

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 301043 | GAMMA | LAL | Potassium-40 | 6270 | | pCi/Kg | 780 |
| 301043 | GAMMA | LAL | Radium-223 | 20 | | pCi/Kg | |
| 301043 | GAMMA | LAL | Thallium-208 | 227 | | pCi/Kg | |
| 301043 | GAMMA | LAL | Thorium-234 | 1200 | | pCi/Kg | 490 |
| 301043 | GAMMA | LAL | Uranium-235 | 67 | | pCi/Kg | 100 |
| 301043 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg | |
| 301043 | ICP-MS | LAL | Beryllium | 0.22 | B | mg/Kg | |
| 301043 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301043 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301043 | ICP-MS | LAL | Thorium-232 | 3.9 | | mg/Kg | |
| 301043 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301043 | ICP-MS | LAL | Uranium-238 | 0.52 | | mg/Kg | |
| 301043 | NAA | ORN | Thorium-232 | 6.3 | | mg/Kg | |
| 301043 | NAA | ORN | Uranium-235 | 0.0137 | | mg/Kg | |
| 301043 | NAA | ORN | Uranium-238 | 1.4 | | mg/Kg | |
| 301043 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 25.58 | | % | |
| 301044 | ALPHA | LAL | Thorium-228 | 580 | | pCi/Kg | 110 |
| 301044 | ALPHA | LAL | Thorium-230 | 476 | | pCi/Kg | 88 |
| 301044 | ALPHA | LAL | Thorium-232 | 563 | | pCi/Kg | 95 |
| 301044 | ALPHA | LAL | Uranium-233/234 | 680 | | pCi/Kg | 120 |
| 301044 | ALPHA | LAL | Uranium-235 | 78 | | pCi/Kg | 39 |
| 301044 | ALPHA | LAL | Uranium-238 | 610 | | pCi/Kg | 110 |
| 301044 | BETA | LAL | Technetium-99 | -200 | | pCi/Kg | 170 |
| 301044 | GAMMA | LAL | Actinium-228 | 650 | | pCi/Kg | |
| 301044 | GAMMA | LAL | Bismuth-212 | 250 | | pCi/Kg | |
| 301044 | GAMMA | LAL | Bismuth-214 | 479 | | pCi/Kg | |
| 301044 | GAMMA | LAL | Cesium-137 | 1 | | pCi/Kg | 16 |
| 301044 | GAMMA | LAL | Cobalt 60 | 0.1 | | pCi/Kg | |
| 301044 | GAMMA | LAL | Lead-210 | 8000 | | pCi/Kg | |
| 301044 | GAMMA | LAL | Lead-212 | 615 | | pCi/Kg | |
| 301044 | GAMMA | LAL | Lead-214 | 625 | | pCi/Kg | |
| 301044 | GAMMA | LAL | Potassium-40 | 1350 | | pCi/Kg | 320 |
| 301044 | GAMMA | LAL | Radium-223 | -10 | | pCi/Kg | |
| 301044 | GAMMA | LAL | Thallium-208 | 209 | | pCi/Kg | |
| 301044 | GAMMA | LAL | Thorium-234 | 1200 | | pCi/Kg | 510 |
| 301044 | GAMMA | LAL | Uranium-235 | 70 | | pCi/Kg | 110 |
| 301044 | ICP-MS | LAL | Antimony | 0.18 | U | mg/Kg | |
| 301044 | ICP-MS | LAL | Beryllium | 0.37 | B | mg/Kg | |
| 301044 | ICP-MS | LAL | Cadmium | 0.18 | U | mg/Kg | |
| 301044 | ICP-MS | LAL | Thallium | 0.18 | U | mg/Kg | |
| 301044 | ICP-MS | LAL | Thorium-232 | 4.3 | | mg/Kg | |
| 301044 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301044 | ICP-MS | LAL | Uranium-238 | 0.77 | | mg/Kg | |
| 301044 | NAA | ORN | Thorium-232 | 5.4 | | mg/Kg | |
| 301044 | NAA | ORN | Uranium-235 | 0.0141 | | mg/Kg | |
| 301044 | NAA | ORN | Uranium-238 | 1.8 | | mg/Kg | |
| 301044 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 8.98 | | % | |
| 301047 | ALPHA | LAL | Thorium-228 | 1190 | | pCi/Kg | 160 |
| 301047 | ALPHA | LAL | Thorium-230 | 900 | | pCi/Kg | 130 |

# Background Soils Project Analytical Data

3/10/97

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 301047 | ALPHA | LAL | Thorium-232 | 1120 | | pCi/Kg | 140 |
| 301047 | ALPHA | LAL | Uranium-233/234 | 910 | | pCi/Kg | 130 |
| 301047 | ALPHA | LAL | Uranium-235 | 56 | | pCi/Kg | 30 |
| 301047 | ALPHA | LAL | Uranium-238 | 900 | | pCi/Kg | 130 |
| 301047 | BETA | LAL | Technetium-99 | -50 | | pCi/Kg | 180 |
| 301047 | GAMMA | LAL | Actinium-228 | 1110 | | pCi/Kg | |
| 301047 | GAMMA | LAL | Bismuth-212 | 630 | | pCi/Kg | |
| 301047 | GAMMA | LAL | Bismuth-214 | 960 | | pCi/Kg | |
| 301047 | GAMMA | LAL | Cesium-137 | -31 | | pCi/Kg | 20 |
| 301047 | GAMMA | LAL | Cobalt 60 | -5 | | pCi/Kg | |
| 301047 | GAMMA | LAL | Lead-210 | 5400 | | pCi/Kg | |
| 301047 | GAMMA | LAL | Lead-212 | 1140 | | pCi/Kg | |
| 301047 | GAMMA | LAL | Lead-214 | 1140 | | pCi/Kg | |
| 301047 | GAMMA | LAL | Potassium-40 | 2360 | | pCi/Kg | 560 |
| 301047 | GAMMA | LAL | Radium-223 | -50 | | pCi/Kg | |
| 301047 | GAMMA | LAL | Thallium-208 | 371 | | pCi/Kg | |
| 301047 | GAMMA | LAL | Thorium-234 | 1950 | | pCi/Kg | 520 |
| 301047 | GAMMA | LAL | Uranium-235 | 50 | | pCi/Kg | 140 |
| 301047 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg | |
| 301047 | ICP-MS | LAL | Beryllium | 0.52 | B | mg/Kg | |
| 301047 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301047 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301047 | ICP-MS | LAL | Thorium-232 | 6.9 | | mg/Kg | |
| 301047 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301047 | ICP-MS | LAL | Uranium-238 | 1.1 | | mg/Kg | |
| 301047 | NAA | ORN | Thorium-232 | 9.6 | | mg/Kg | |
| 301047 | NAA | ORN | Uranium-235 | 0.022 | | mg/Kg | |
| 301047 | NAA | ORN | Uranium-238 | 2.6 | | mg/Kg | |
| 301047 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 29.48 | | % | |
| 301048 | ALPHA | LAL | Thorium-228 | 1040 | | pCi/Kg | 160 |
| 301048 | ALPHA | LAL | Thorium-230 | 1100 | | pCi/Kg | 150 |
| 301048 | ALPHA | LAL | Thorium-232 | 970 | | pCi/Kg | 140 |
| 301048 | ALPHA | LAL | Uranium-233/234 | 1450 | | pCi/Kg | 170 |
| 301048 | ALPHA | LAL | Uranium-235 | 58 | | pCi/Kg | 32 |
| 301048 | ALPHA | LAL | Uranium-238 | 1300 | | pCi/Kg | 160 |
| 301048 | BETA | LAL | Technetium-99 | -190 | | pCi/Kg | 170 |
| 301048 | GAMMA | LAL | Actinium-228 | 1110 | | pCi/Kg | |
| 301048 | GAMMA | LAL | Bismuth-212 | 900 | | pCi/Kg | |
| 301048 | GAMMA | LAL | Bismuth-214 | 1030 | | pCi/Kg | |
| 301048 | GAMMA | LAL | Cesium-137 | -4 | | pCi/Kg | 21 |
| 301048 | GAMMA | LAL | Cobalt 60 | -1 | | pCi/Kg | |
| 301048 | GAMMA | LAL | Lead-210 | 12000 | | pCi/Kg | |
| 301048 | GAMMA | LAL | Lead-212 | 1200 | | pCi/Kg | |
| 301048 | GAMMA | LAL | Lead-214 | 1310 | | pCi/Kg | |
| 301048 | GAMMA | LAL | Potassium-40 | 4010 | | pCi/Kg | 700 |
| 301048 | GAMMA | LAL | Radium-223 | 30 | | pCi/Kg | |
| 301048 | GAMMA | LAL | Thallium-208 | 311 | | pCi/Kg | |
| 301048 | GAMMA | LAL | Thorium-234 | 1450 | | pCi/Kg | 850 |
| 301048 | GAMMA | LAL | Uranium-235 | 230 | | pCi/Kg | 170 |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|
| 301048 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg |
| 301048 | ICP-MS | LAL | Beryllium | 1.3 | | mg/Kg |
| 301048 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg |
| 301048 | ICP-MS | LAL | Thallium | 0.21 | B | mg/Kg |
| 301048 | ICP-MS | LAL | Thorium-232 | 6.3 | | mg/Kg |
| 301048 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg |
| 301048 | ICP-MS | LAL | Uranium-238 | 2.1 | | mg/Kg |
| 301048 | NAA | ORN | Thorium-232 | 10.1 | | mg/Kg |
| 301048 | NAA | ORN | Uranium-235 | 0.026 | | mg/Kg |
| 301048 | NAA | ORN | Uranium-238 | 4.1 | | mg/Kg |
| 301048 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 38.43 | | % |

# Background Soils Project Analytical Data

3/10/97

## Location 194-03,04

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301036 | ALPHA | LAL | Thorium-228 | 890 | | pCi/Kg | 140 |
| 301036 | ALPHA | LAL | Thorium-230 | 770 | | pCi/Kg | 120 |
| 301036 | ALPHA | LAL | Thorium-232 | 880 | | pCi/Kg | 130 |
| 301036 | ALPHA | LAL | Uranium-233/234 | 790 | | pCi/Kg | 120 |
| 301036 | ALPHA | LAL | Uranium-235 | 43 | | pCi/Kg | 26 |
| 301036 | ALPHA | LAL | Uranium-238 | 800 | | pCi/Kg | 120 |
| 301036 | BETA | LAL | Technetium-99 | -120 | | pCi/Kg | 180 |
| 301036 | GAMMA | LAL | Actinium-228 | 1000 | | pCi/Kg | |
| 301036 | GAMMA | LAL | Bismuth-212 | 510 | | pCi/Kg | |
| 301036 | GAMMA | LAL | Bismuth-214 | 810 | | pCi/Kg | |
| 301036 | GAMMA | LAL | Cesium-137 | -27 | | pCi/Kg | 20 |
| 301036 | GAMMA | LAL | Cobalt 60 | -16 | | pCi/Kg | |
| 301036 | GAMMA | LAL | Lead-210 | 1480 | | pCi/Kg | |
| 301036 | GAMMA | LAL | Lead-212 | 1050 | | pCi/Kg | |
| 301036 | GAMMA | LAL | Lead-214 | 1130 | | pCi/Kg | |
| 301036 | GAMMA | LAL | Potassium-40 | 12000 | | pCi/Kg | 1600 |
| 301036 | GAMMA | LAL | Radium-223 | -10 | | pCi/Kg | |
| 301036 | GAMMA | LAL | Thallium-208 | 279 | | pCi/Kg | |
| 301036 | GAMMA | LAL | Thorium-234 | 1260 | | pCi/Kg | 420 |
| 301036 | GAMMA | LAL | Uranium-235 | 90 | | pCi/Kg | 150 |
| 301036 | ICP-MS | LAL | Antimony | 0.19 | U | mg/Kg | |
| 301036 | ICP-MS | LAL | Beryllium | 0.48 | B | mg/Kg | |
| 301036 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301036 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301036 | ICP-MS | LAL | Thorium-232 | 5.5 | | mg/Kg | |
| 301036 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301036 | ICP-MS | LAL | Uranium-238 | 0.63 | | mg/Kg | |
| 301036 | NAA | ORN | Thorium-232 | 7.9 | | mg/Kg | |
| 301036 | NAA | ORN | Uranium-235 | 0.017 | | mg/Kg | |
| 301036 | NAA | ORN | Uranium-238 | 2.3 | | mg/Kg | |
| 301036 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 19.04 | | % | |
| 301041 | ALPHA | LAL | Thorium-228 | 1040 | | pCi/Kg | 160 |
| 301041 | ALPHA | LAL | Thorium-230 | 980 | | pCi/Kg | 150 |
| 301041 | ALPHA | LAL | Thorium-232 | 910 | | pCi/Kg | 140 |
| 301041 | ALPHA | LAL | Uranium-233/234 | 790 | | pCi/Kg | 120 |
| 301041 | ALPHA | LAL | Uranium-235 | 103 | | pCi/Kg | 44 |
| 301041 | ALPHA | LAL | Uranium-238 | 810 | | pCi/Kg | 120 |
| 301041 | BETA | LAL | Technetium-99 | -130 | | pCi/Kg | 190 |
| 301041 | GAMMA | LAL | Actinium-228 | 1050 | | pCi/Kg | |
| 301041 | GAMMA | LAL | Bismuth-212 | 590 | | pCi/Kg | |
| 301041 | GAMMA | LAL | Bismuth-214 | 780 | | pCi/Kg | |
| 301041 | GAMMA | LAL | Cesium-137 | -9 | | pCi/Kg | 22 |
| 301041 | GAMMA | LAL | Cobalt 60 | -2 | | pCi/Kg | |
| 301041 | GAMMA | LAL | Lead-210 | 1040 | | pCi/Kg | |
| 301041 | GAMMA | LAL | Lead-212 | 1160 | | pCi/Kg | |
| 301041 | GAMMA | LAL | Lead-214 | 1030 | | pCi/Kg | |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301041 | GAMMA | LAL | Potassium-40 | 10400 | | pCi/Kg | 1500 |
| 301041 | GAMMA | LAL | Radium-223 | -90 | | pCi/Kg | |
| 301041 | GAMMA | LAL | Thallium-208 | 295 | | pCi/Kg | |
| 301041 | GAMMA | LAL | Thorium-234 | 1310 | | pCi/Kg | 420 |
| 301041 | GAMMA | LAL | Uranium-235 | 20 | | pCi/Kg | 140 |
| 301041 | ICP-MS | LAL | Antimony | 0.19 | U | mg/Kg | |
| 301041 | ICP-MS | LAL | Beryllium | 0.48 | B | mg/Kg | |
| 301041 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301041 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301041 | ICP-MS | LAL | Thorium-232 | 6 | | mg/Kg | |
| 301041 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301041 | ICP-MS | LAL | Uranium-238 | 0.69 | | mg/Kg | |
| 301041 | NAA | ORN | Thorium-232 | 8.2 | | mg/Kg | |
| 301041 | NAA | ORN | Uranium-235 | 0.017 | | mg/Kg | |
| 301041 | NAA | ORN | Uranium-238 | 2.4 | | mg/Kg | |
| 301041 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 21.42 | | % | |
| 301045 | ALPHA | LAL | Thorium-228 | 1000 | | pCi/Kg | 150 |
| 301045 | ALPHA | LAL | Thorium-230 | 750 | | pCi/Kg | 120 |
| 301045 | ALPHA | LAL | Thorium-232 | 960 | | pCi/Kg | 140 |
| 301045 | ALPHA | LAL | Uranium-233/234 | 960 | | pCi/Kg | 140 |
| 301045 | ALPHA | LAL | Uranium-235 | 90 | | pCi/Kg | 39 |
| 301045 | ALPHA | LAL | Uranium-238 | 1060 | | pCi/Kg | 140 |
| 301045 | BETA | LAL | Technetium-99 | -70 | | pCi/Kg | 180 |
| 301045 | GAMMA | LAL | Actinium-228 | 990 | | pCi/Kg | |
| 301045 | GAMMA | LAL | Bismuth-212 | 450 | | pCi/Kg | |
| 301045 | GAMMA | LAL | Bismuth-214 | 1010 | | pCi/Kg | |
| 301045 | GAMMA | LAL | Cesium-137 | -32 | | pCi/Kg | 24 |
| 301045 | GAMMA | LAL | Cobalt 60 | -1 | | pCi/Kg | |
| 301045 | GAMMA | LAL | Lead-210 | 1680 | | pCi/Kg | |
| 301045 | GAMMA | LAL | Lead-212 | 1100 | | pCi/Kg | |
| 301045 | GAMMA | LAL | Lead-214 | 1040 | | pCi/Kg | |
| 301045 | GAMMA | LAL | Potassium-40 | 5380 | | pCi/Kg | 930 |
| 301045 | GAMMA | LAL | Radium-223 | -140 | | pCi/Kg | |
| 301045 | GAMMA | LAL | Thallium-208 | 344 | | pCi/Kg | |
| 301045 | GAMMA | LAL | Thorium-234 | 1680 | | pCi/Kg | 420 |
| 301045 | GAMMA | LAL | Uranium-235 | 150 | | pCi/Kg | 150 |
| 301045 | ICP-MS | LAL | Antimony | 0.19 | U | mg/Kg | |
| 301045 | ICP-MS | LAL | Beryllium | 0.46 | B | mg/Kg | |
| 301045 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301045 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301045 | ICP-MS | LAL | Thorium-232 | 6 | | mg/Kg | |
| 301045 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301045 | ICP-MS | LAL | Uranium-238 | 0.9 | | mg/Kg | |
| 301045 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 15.28 | | % | |
| 301046 | ALPHA | LAL | Thorium-228 | 1060 | | pCi/Kg | 150 |
| 301046 | ALPHA | LAL | Thorium-230 | 860 | | pCi/Kg | 130 |
| 301046 | ALPHA | LAL | Thorium-232 | 940 | | pCi/Kg | 130 |
| 301046 | ALPHA | LAL | Uranium-233/234 | 1140 | | pCi/Kg | 160 |
| 301046 | ALPHA | LAL | Uranium-235 | 57 | | pCi/Kg | 35 |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301046 | ALPHA | LAL | Uranium-238 | 1180 | | pCi/Kg | 160 |
| 301046 | BETA | LAL | Technetium-99 | -120 | | pCi/Kg | 180 |
| 301046 | GAMMA | LAL | Actinium-228 | 1000 | | pCi/Kg | |
| 301046 | GAMMA | LAL | Bismuth-212 | 550 | | pCi/Kg | |
| 301046 | GAMMA | LAL | Bismuth-214 | 803 | | pCi/Kg | |
| 301046 | GAMMA | LAL | Cesium-137 | 1 | | pCi/Kg | 18 |
| 301046 | GAMMA | LAL | Cobalt 60 | 0.4 | | pCi/Kg | |
| 301046 | GAMMA | LAL | Lead-210 | 600 | | pCi/Kg | |
| 301046 | GAMMA | LAL | Lead-212 | 950 | | pCi/Kg | |
| 301046 | GAMMA | LAL | Lead-214 | 989 | | pCi/Kg | |
| 301046 | GAMMA | LAL | Potassium-40 | 2810 | | pCi/Kg | 470 |
| 301046 | GAMMA | LAL | Radium-223 | -100 | | pCi/Kg | |
| 301046 | GAMMA | LAL | Thallium-208 | 331 | | pCi/Kg | |
| 301046 | GAMMA | LAL | Thorium-234 | 1130 | | pCi/Kg | 370 |
| 301046 | GAMMA | LAL | Uranium-235 | -32 | | pCi/Kg | 98 |
| 301046 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg | |
| 301046 | ICP-MS | LAL | Beryllium | 0.49 | B | mg/Kg | |
| 301046 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301046 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301046 | ICP-MS | LAL | Thorium-232 | 6.3 | | mg/Kg | |
| 301046 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301046 | ICP-MS | LAL | Uranium-238 | 1.1 | | mg/Kg | |
| 301046 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 33.11 | | % | |
| 301051 | ALPHA | LAL | Thorium-228 | 1040 | | pCi/Kg | 160 |
| 301051 | ALPHA | LAL | Thorium-230 | 990 | | pCi/Kg | 140 |
| 301051 | ALPHA | LAL | Thorium-232 | 980 | | pCi/Kg | 140 |
| 301051 | ALPHA | LAL | Uranium-233/234 | 840 | B | pCi/Kg | 130 |
| 301051 | ALPHA | LAL | Uranium-235 | 78 | | pCi/Kg | 38 |
| 301051 | ALPHA | LAL | Uranium-238 | 750 | | pCi/Kg | 120 |
| 301051 | BETA | LAL | Technetium-99 | -33 | | pCi/Kg | 93 |
| 301051 | GAMMA | LAL | Actinium-228 | 1120 | | pCi/Kg | |
| 301051 | GAMMA | LAL | Bismuth-214 | 960 | B | pCi/Kg | |
| 301051 | GAMMA | LAL | Cesium-134 | 6 | | pCi/Kg | 22 |
| 301051 | GAMMA | LAL | Cesium-137 | 16 | | pCi/Kg | 31 |
| 301051 | GAMMA | LAL | Cobalt 60 | 8 | | pCi/Kg | |
| 301051 | GAMMA | LAL | Cobalt-57 | -8 | | pCi/Kg | 13 |
| 301051 | GAMMA | LAL | Lead-212 | 1250 | | pCi/Kg | |
| 301051 | GAMMA | LAL | Lead-214 | 1210 | B | pCi/Kg | |
| 301051 | GAMMA | LAL | Potassium-40 | 10000 | | pCi/Kg | 1500 |
| 301051 | GAMMA | LAL | Thallium-208 | 374 | | pCi/Kg | |
| 301051 | GAMMA | LAL | Thorium-234 | 1260 | | pCi/Kg | 820 |
| 301051 | GAMMA | LAL | Uranium-235 | -10 | | pCi/Kg | 150 |
| 301051 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg | |
| 301051 | ICP-MS | LAL | Beryllium | 0.45 | B | mg/Kg | |
| 301051 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301051 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301051 | ICP-MS | LAL | Thorium-232 | 6 | | mg/Kg | |
| 301051 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301051 | ICP-MS | LAL | Uranium-238 | 0.65 | | mg/Kg | |

# Background Soils Project Analytical Data

3/10/97

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|---|---|---|---|---|---|
| 301051 | NAA | ORN | Thorium-232 | 8.9 | mg/Kg |
| 301051 | NAA | ORN | Uranium-235 | 0.018 | mg/Kg |
| 301051 | NAA | ORN | Uranium-238 | 2.1 | mg/Kg |
| 301051 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 21.85 | % |

# Background Soils Project Analytical Data

3/10/97

## Location 194-05,06

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301039 | ALPHA | LAL | Thorium-228 | 970 | | pCi/Kg | 150 |
| 301039 | ALPHA | LAL | Thorium-230 | 970 | | pCi/Kg | 140 |
| 301039 | ALPHA | LAL | Thorium-232 | 970 | | pCi/Kg | 140 |
| 301039 | ALPHA | LAL | Uranium-233/234 | 890 | | pCi/Kg | 130 |
| 301039 | ALPHA | LAL | Uranium-235 | 59 | | pCi/Kg | 35 |
| 301039 | ALPHA | LAL | Uranium-238 | 790 | | pCi/Kg | 120 |
| 301039 | BETA | LAL | Technetium-99 | -110 | | pCi/Kg | 180 |
| 301039 | GAMMA | LAL | Actinium-228 | 1070 | | pCi/Kg | |
| 301039 | GAMMA | LAL | Bismuth-212 | 870 | | pCi/Kg | |
| 301039 | GAMMA | LAL | Bismuth-214 | 680 | | pCi/Kg | |
| 301039 | GAMMA | LAL | Cesium-137 | 25 | | pCi/Kg | 35 |
| 301039 | GAMMA | LAL | Cobalt 60 | 11 | | pCi/Kg | |
| 301039 | GAMMA | LAL | Lead-210 | 1720 | | pCi/Kg | |
| 301039 | GAMMA | LAL | Lead-212 | 1000 | | pCi/Kg | |
| 301039 | GAMMA | LAL | Lead-214 | 820 | | pCi/Kg | |
| 301039 | GAMMA | LAL | Potassium-40 | 13700 | | pCi/Kg | 1800 |
| 301039 | GAMMA | LAL | Radium-223 | 140 | | pCi/Kg | |
| 301039 | GAMMA | LAL | Thallium-208 | 287 | | pCi/Kg | |
| 301039 | GAMMA | LAL | Thorium-234 | 1160 | | pCi/Kg | 430 |
| 301039 | GAMMA | LAL | Uranium-235 | 110 | | pCi/Kg | 150 |
| 301039 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg | |
| 301039 | ICP-MS | LAL | Beryllium | 0.48 | B | mg/Kg | |
| 301039 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301039 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301039 | ICP-MS | LAL | Thorium-232 | 6.3 | | mg/Kg | |
| 301039 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301039 | ICP-MS | LAL | Uranium-238 | 0.73 | | mg/Kg | |
| 301039 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 19.44 | | % | |
| 301042 | ALPHA | LAL | Thorium-228 | 1090 | | pCi/Kg | 160 |
| 301042 | ALPHA | LAL | Thorium-230 | 1520 | | pCi/Kg | 180 |
| 301042 | ALPHA | LAL | Thorium-232 | 1230 | | pCi/Kg | 160 |
| 301042 | ALPHA | LAL | Uranium-233/234 | 890 | | pCi/Kg | 130 |
| 301042 | ALPHA | LAL | Uranium-235 | 86 | | pCi/Kg | 37 |
| 301042 | ALPHA | LAL | Uranium-238 | 720 | | pCi/Kg | 110 |
| 301042 | BETA | LAL | Technetium-99 | -230 | | pCi/Kg | 170 |
| 301042 | GAMMA | LAL | Actinium-228 | 1020 | | pCi/Kg | |
| 301042 | GAMMA | LAL | Bismuth-212 | 690 | | pCi/Kg | |
| 301042 | GAMMA | LAL | Bismuth-214 | 740 | | pCi/Kg | |
| 301042 | GAMMA | LAL | Cesium-137 | -25 | | pCi/Kg | 24 |
| 301042 | GAMMA | LAL | Cobalt 60 | -13 | | pCi/Kg | |
| 301042 | GAMMA | LAL | Lead-210 | 1170 | | pCi/Kg | |
| 301042 | GAMMA | LAL | Lead-212 | 1080 | | pCi/Kg | |
| 301042 | GAMMA | LAL | Lead-214 | 970 | | pCi/Kg | |
| 301042 | GAMMA | LAL | Potassium-40 | 12000 | | pCi/Kg | 1600 |
| 301042 | GAMMA | LAL | Radium-223 | 170 | | pCi/Kg | |
| 301042 | GAMMA | LAL | Thallium-208 | 327 | | pCi/Kg | |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301042 | GAMMA | LAL | Thorium-234 | 1310 | | pCi/Kg | 420 |
| 301042 | GAMMA | LAL | Uranium-235 | 50 | | pCi/Kg | 140 |
| 301042 | ICP-MS | LAL | Antimony | 0.19 | U | mg/Kg | |
| 301042 | ICP-MS | LAL | Beryllium | 0.51 | B | mg/Kg | |
| 301042 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301042 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301042 | ICP-MS | LAL | Thorium-232 | 6.1 | | mg/Kg | |
| 301042 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301042 | ICP-MS | LAL | Uranium-238 | 0.76 | | mg/Kg | |
| 301042 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 21.73 | | % | |
| 301050 | ALPHA | LAL | Thorium-228 | 1130 | | pCi/Kg | 160 |
| 301050 | ALPHA | LAL | Thorium-230 | 800 | | pCi/Kg | 120 |
| 301050 | ALPHA | LAL | Thorium-232 | 1140 | | pCi/Kg | 150 |
| 301050 | ALPHA | LAL | Uranium-233/234 | 770 | | pCi/Kg | 120 |
| 301050 | ALPHA | LAL | Uranium-235 | 32 | | pCi/Kg | 26 |
| 301050 | ALPHA | LAL | Uranium-238 | 710 | | pCi/Kg | 110 |
| 301050 | BETA | LAL | Technetium-99 | -70 | | pCi/Kg | 180 |
| 301050 | GAMMA | LAL | Actinium-228 | 1110 | | pCi/Kg | |
| 301050 | GAMMA | LAL | Bismuth-212 | 520 | | pCi/Kg | |
| 301050 | GAMMA | LAL | Bismuth-214 | 750 | | pCi/Kg | |
| 301050 | GAMMA | LAL | Cesium-137 | -12 | | pCi/Kg | 20 |
| 301050 | GAMMA | LAL | Cobalt 60 | -10 | | pCi/Kg | |
| 301050 | GAMMA | LAL | Lead-210 | 1200 | | pCi/Kg | |
| 301050 | GAMMA | LAL | Lead-212 | 930 | | pCi/Kg | |
| 301050 | GAMMA | LAL | Lead-214 | 930 | | pCi/Kg | |
| 301050 | GAMMA | LAL | Potassium-40 | 5560 | | pCi/Kg | 880 |
| 301050 | GAMMA | LAL | Radium-223 | -150 | | pCi/Kg | |
| 301050 | GAMMA | LAL | Thallium-208 | 338 | | pCi/Kg | |
| 301050 | GAMMA | LAL | Thorium-234 | 900 | | pCi/Kg | 490 |
| 301050 | GAMMA | LAL | Uranium-235 | 40 | | pCi/Kg | 130 |
| 301050 | ICP-MS | LAL | Antimony | 0.21 | U | mg/Kg | |
| 301050 | ICP-MS | LAL | Beryllium | 0.47 | B | mg/Kg | |
| 301050 | ICP-MS | LAL | Cadmium | 0.21 | U | mg/Kg | |
| 301050 | ICP-MS | LAL | Thallium | 0.21 | B | mg/Kg | |
| 301050 | ICP-MS | LAL | Thorium-232 | 6.7 | | mg/Kg | |
| 301050 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301050 | ICP-MS | LAL | Uranium-238 | 0.76 | | mg/Kg | |
| 301050 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 34.35 | | % | |
| 301057 | ALPHA | LAL | Thorium-228 | 1430 | | pCi/Kg | 190 |
| 301057 | ALPHA | LAL | Thorium-230 | 870 | | pCi/Kg | 140 |
| 301057 | ALPHA | LAL | Thorium-232 | 1330 | | pCi/Kg | 180 |
| 301057 | ALPHA | LAL | Uranium-233/234 | 1040 | B | pCi/Kg | 160 |
| 301057 | ALPHA | LAL | Uranium-235 | 74 | | pCi/Kg | 39 |
| 301057 | ALPHA | LAL | Uranium-238 | 1020 | | pCi/Kg | 150 |
| 301057 | BETA | LAL | Technetium-99 | 143 | | pCi/Kg | 100 |
| 301057 | GAMMA | LAL | Actinium-228 | 1450 | | pCi/Kg | |
| 301057 | GAMMA | LAL | Bismuth-214 | 880 | B | pCi/Kg | |
| 301057 | GAMMA | LAL | Cesium-134 | 11 | | pCi/Kg | 14 |
| 301057 | GAMMA | LAL | Cesium-137 | -10 | | pCi/Kg | 19 |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301057 | GAMMA | LAL | Cobalt 60 | 1 | | pCi/Kg | |
| 301057 | GAMMA | LAL | Cobalt-57 | -6 | | pCi/Kg | 13 |
| 301057 | GAMMA | LAL | Lead-212 | 1290 | | pCi/Kg | |
| 301057 | GAMMA | LAL | Lead-214 | 1080 | B | pCi/Kg | |
| 301057 | GAMMA | LAL | Potassium-40 | 7800 | | pCi/Kg | 1000 |
| 301057 | GAMMA | LAL | Thallium-208 | 409 | | pCi/Kg | |
| 301057 | GAMMA | LAL | Thorium-234 | 1080 | | pCi/Kg | 450 |
| 301057 | GAMMA | LAL | Uranium-235 | 30 | | pCi/Kg | 130 |
| 301057 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg | |
| 301057 | ICP-MS | LAL | Beryllium | 0.91 | B | mg/Kg | |
| 301057 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301057 | ICP-MS | LAL | Thallium | 0.27 | B | mg/Kg | |
| 301057 | ICP-MS | LAL | Thorium-232 | 8 | | mg/Kg | |
| 301057 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301057 | ICP-MS | LAL | Uranium-238 | 1 | | mg/Kg | |
| 301057 | NAA | ORN | Thorium-232 | 10.5 | | mg/Kg | |
| 301057 | NAA | ORN | Uranium-235 | 0.017 | | mg/Kg | |
| 301057 | NAA | ORN | Uranium-238 | 2.25 | | mg/Kg | |
| 301057 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 70.79 | | % | |
| 301058 | ALPHA | LAL | Thorium-228 | 1270 | | pCi/Kg | 190 |
| 301058 | ALPHA | LAL | Thorium-230 | 1430 | | pCi/Kg | 190 |
| 301058 | ALPHA | LAL | Thorium-232 | 1290 | | pCi/Kg | 180 |
| 301058 | ALPHA | LAL | Uranium-233/234 | 1540 | B | pCi/Kg | 200 |
| 301058 | ALPHA | LAL | Uranium-235 | 150 | | pCi/Kg | 58 |
| 301058 | ALPHA | LAL | Uranium-238 | 1550 | | pCi/Kg | 200 |
| 301058 | BETA | LAL | Technetium-99 | -41 | | pCi/Kg | 91 |
| 301058 | GAMMA | LAL | Actinium-228 | 1170 | | pCi/Kg | |
| 301058 | GAMMA | LAL | Bismuth-214 | 1150 | B | pCi/Kg | |
| 301058 | GAMMA | LAL | Cesium-134 | -5 | | pCi/Kg | 25 |
| 301058 | GAMMA | LAL | Cesium-137 | -39 | | pCi/Kg | 34 |
| 301058 | GAMMA | LAL | Cobalt 60 | 7 | | pCi/Kg | |
| 301058 | GAMMA | LAL | Cobalt-57 | 0 | | pCi/Kg | 22 |
| 301058 | GAMMA | LAL | Lead-212 | 1340 | | pCi/Kg | |
| 301058 | GAMMA | LAL | Lead-214 | 1470 | B | pCi/Kg | |
| 301058 | GAMMA | LAL | Potassium-40 | 9600 | | pCi/Kg | 1500 |
| 301058 | GAMMA | LAL | Thallium-208 | 414 | | pCi/Kg | |
| 301058 | GAMMA | LAL | Thorium-234 | 1490 | | pCi/Kg | 490 |
| 301058 | GAMMA | LAL | Uranium-235 | -30 | | pCi/Kg | 160 |
| 301058 | ICP-MS | LAL | Antimony | 0.19 | U | mg/Kg | |
| 301058 | ICP-MS | LAL | Beryllium | 1.6 | | mg/Kg | |
| 301058 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301058 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301058 | ICP-MS | LAL | Thorium-232 | 7.1 | | mg/Kg | |
| 301058 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301058 | ICP-MS | LAL | Uranium-238 | 2.5 | | mg/Kg | |
| 301058 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 60.87 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location 196-01,02

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301037 | ALPHA | LAL | Thorium-228 | 1090 | | pCi/Kg | 150 |
| 301037 | ALPHA | LAL | Thorium-230 | 1040 | | pCi/Kg | 140 |
| 301037 | ALPHA | LAL | Thorium-232 | 940 | | pCi/Kg | 130 |
| 301037 | ALPHA | LAL | Uranium-233/234 | 820 | | pCi/Kg | 120 |
| 301037 | ALPHA | LAL | Uranium-235 | 38 | | pCi/Kg | 26 |
| 301037 | ALPHA | LAL | Uranium-238 | 820 | | pCi/Kg | 120 |
| 301037 | BETA | LAL | Technetium-99 | -250 | | pCi/Kg | 360 |
| 301037 | GAMMA | LAL | Actinium-228 | 990 | | pCi/Kg | |
| 301037 | GAMMA | LAL | Bismuth-212 | 400 | | pCi/Kg | |
| 301037 | GAMMA | LAL | Bismuth-214 | 491 | | pCi/Kg | |
| 301037 | GAMMA | LAL | Cesium-137 | -13 | | pCi/Kg | 16 |
| 301037 | GAMMA | LAL | Cobalt 60 | -15 | | pCi/Kg | |
| 301037 | GAMMA | LAL | Lead-210 | 0 | | pCi/Kg | |
| 301037 | GAMMA | LAL | Lead-212 | 830 | | pCi/Kg | |
| 301037 | GAMMA | LAL | Lead-214 | 744 | | pCi/Kg | |
| 301037 | GAMMA | LAL | Potassium-40 | 13200 | | pCi/Kg | 1700 |
| 301037 | GAMMA | LAL | Radium-223 | 50 | | pCi/Kg | |
| 301037 | GAMMA | LAL | Thallium-208 | 289 | | pCi/Kg | |
| 301037 | GAMMA | LAL | Thorium-234 | 1010 | | pCi/Kg | 490 |
| 301037 | GAMMA | LAL | Uranium-235 | -20 | | pCi/Kg | 130 |
| 301037 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg | |
| 301037 | ICP-MS | LAL | Beryllium | 0.47 | B | mg/Kg | |
| 301037 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301037 | ICP-MS | LAL | Thallium | 0.2 | B | mg/Kg | |
| 301037 | ICP-MS | LAL | Thorium-232 | 5.9 | | mg/Kg | |
| 301037 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301037 | ICP-MS | LAL | Uranium-238 | 1.1 | | mg/Kg | |
| 301037 | NAA | ORN | Thorium-232 | 8.1 | | mg/Kg | |
| 301037 | NAA | ORN | Uranium-235 | 0.019 | | mg/Kg | |
| 301037 | NAA | ORN | Uranium-238 | 2.4 | | mg/Kg | |
| 301037 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 18.85 | | % | |
| 301053 | ALPHA | LAL | Thorium-228 | 410 | | pCi/Kg | 100 |
| 301053 | ALPHA | LAL | Thorium-230 | 247 | | pCi/Kg | 69 |
| 301053 | ALPHA | LAL | Thorium-232 | 409 | | pCi/Kg | 87 |
| 301053 | ALPHA | LAL | Uranium-233/234 | 345 | B | pCi/Kg | 76 |
| 301053 | ALPHA | LAL | Uranium-235 | 32 | | pCi/Kg | 24 |
| 301053 | ALPHA | LAL | Uranium-238 | 301 | | pCi/Kg | 70 |
| 301053 | BETA | LAL | Technetium-99 | -76 | | pCi/Kg | 88 |
| 301053 | GAMMA | LAL | Actinium-228 | 460 | | pCi/Kg | |
| 301053 | GAMMA | LAL | Bismuth-214 | 268 | B | pCi/Kg | |
| 301053 | GAMMA | LAL | Cesium-134 | 8 | | pCi/Kg | 15 |
| 301053 | GAMMA | LAL | Cesium-137 | -10 | | pCi/Kg | 21 |
| 301053 | GAMMA | LAL | Cobalt 60 | -10 | | pCi/Kg | |
| 301053 | GAMMA | LAL | Cobalt-57 | -2.6 | | pCi/Kg | 9 |
| 301053 | GAMMA | LAL | Lead-212 | 444 | | pCi/Kg | |
| 301053 | GAMMA | LAL | Lead-214 | 319 | B | pCi/Kg | |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301053 | GAMMA | LAL | Potassium-40 | 1560 | | pCi/Kg | 510 |
| 301053 | GAMMA | LAL | Thallium-208 | 185 | | pCi/Kg | |
| 301053 | GAMMA | LAL | Thorium-234 | 450 | | pCi/Kg | 670 |
| 301053 | GAMMA | LAL | Uranium-235 | -77 | | pCi/Kg | 100 |
| 301053 | ICP-MS | LAL | Antimony | 0.19 | U | mg/Kg | |
| 301053 | ICP-MS | LAL | Beryllium | 0.19 | U | mg/Kg | |
| 301053 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301053 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301053 | ICP-MS | LAL | Thorium-232 | 2.8 | | mg/Kg | |
| 301053 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301053 | ICP-MS | LAL | Uranium-238 | 0.27 | | mg/Kg | |
| 301053 | NAA | ORN | Thorium-232 | 3.7 | | mg/Kg | |
| 301053 | NAA | ORN | Uranium-235 | 0.0056 | | mg/Kg | |
| 301053 | NAA | ORN | Uranium-238 | 0.75 | | mg/Kg | |
| 301053 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 15.44 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location 196-03,04

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301038 | ALPHA | LAL | Thorium-228 | 1020 | | pCi/Kg | 150 |
| 301038 | ALPHA | LAL | Thorium-230 | 1040 | | pCi/Kg | 140 |
| 301038 | ALPHA | LAL | Thorium-232 | 1020 | | pCi/Kg | 140 |
| 301038 | ALPHA | LAL | Uranium-233/234 | 810 | | pCi/Kg | 120 |
| 301038 | ALPHA | LAL | Uranium-235 | 71 | | pCi/Kg | 36 |
| 301038 | ALPHA | LAL | Uranium-238 | 800 | | pCi/Kg | 120 |
| 301038 | BETA | LAL | Technetium-99 | -30 | | pCi/Kg | 190 |
| 301038 | GAMMA | LAL | Actinium-228 | 900 | | pCi/Kg | |
| 301038 | GAMMA | LAL | Bismuth-212 | 550 | | pCi/Kg | |
| 301038 | GAMMA | LAL | Bismuth-214 | 710 | | pCi/Kg | |
| 301038 | GAMMA | LAL | Cesium-137 | -23 | | pCi/Kg | 18 |
| 301038 | GAMMA | LAL | Cobalt 60 | 3 | | pCi/Kg | |
| 301038 | GAMMA | LAL | Lead-210 | 2400 | | pCi/Kg | |
| 301038 | GAMMA | LAL | Lead-212 | 800 | | pCi/Kg | |
| 301038 | GAMMA | LAL | Lead-214 | 940 | | pCi/Kg | |
| 301038 | GAMMA | LAL | Potassium-40 | 13300 | | pCi/Kg | 1700 |
| 301038 | GAMMA | LAL | Radium-223 | -220 | | pCi/Kg | |
| 301038 | GAMMA | LAL | Thallium-208 | 282 | | pCi/Kg | |
| 301038 | GAMMA | LAL | Thorium-234 | 690 | | pCi/Kg | 490 |
| 301038 | GAMMA | LAL | Uranium-235 | 80 | | pCi/Kg | 150 |
| 301038 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg | |
| 301038 | ICP-MS | LAL | Beryllium | 0.48 | B | mg/Kg | |
| 301038 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301038 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301038 | ICP-MS | LAL | Thorium-232 | 5.9 | | mg/Kg | |
| 301038 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301038 | ICP-MS | LAL | Uranium-238 | 0.81 | | mg/Kg | |
| 301038 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 16.78 | | % | |
| 301052 | ALPHA | LAL | Thorium-228 | 860 | | pCi/Kg | 140 |
| 301052 | ALPHA | LAL | Thorium-230 | 780 | | pCi/Kg | 120 |
| 301052 | ALPHA | LAL | Thorium-232 | 920 | | pCi/Kg | 130 |
| 301052 | ALPHA | LAL | Uranium-233/234 | 630 | B | pCi/Kg | 100 |
| 301052 | ALPHA | LAL | Uranium-235 | 38 | | pCi/Kg | 25 |
| 301052 | ALPHA | LAL | Uranium-238 | 760 | | pCi/Kg | 110 |
| 301052 | BETA | LAL | Technetium-99 | 59 | | pCi/Kg | 97 |
| 301052 | GAMMA | LAL | Actinium-228 | 770 | | pCi/Kg | |
| 301052 | GAMMA | LAL | Bismuth-214 | 790 | B | pCi/Kg | |
| 301052 | GAMMA | LAL | Cesium-134 | 14 | | pCi/Kg | 19 |
| 301052 | GAMMA | LAL | Cesium-137 | -15 | | pCi/Kg | 28 |
| 301052 | GAMMA | LAL | Cobalt 60 | 19 | | pCi/Kg | |
| 301052 | GAMMA | LAL | Cobalt-57 | -3 | | pCi/Kg | 13 |
| 301052 | GAMMA | LAL | Lead-212 | 910 | | pCi/Kg | |
| 301052 | GAMMA | LAL | Lead-214 | 1120 | B | pCi/Kg | |
| 301052 | GAMMA | LAL | Potassium-40 | 8200 | | pCi/Kg | 1200 |
| 301052 | GAMMA | LAL | Thallium-208 | 281 | | pCi/Kg | |
| 301052 | GAMMA | LAL | Thorium-234 | 1040 | | pCi/Kg | 400 |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301052 | GAMMA | LAL | Uranium-235 | 40 | | pCi/Kg | 130 |
| 301052 | ICP-MS | LAL | Antimony | 0.19 | U | mg/Kg | |
| 301052 | ICP-MS | LAL | Beryllium | 0.38 | B | mg/Kg | |
| 301052 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301052 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301052 | ICP-MS | LAL | Thorium-232 | 4.8 | | mg/Kg | |
| 301052 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301052 | ICP-MS | LAL | Uranium-238 | 0.67 | | mg/Kg | |
| 301052 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 20.76 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location BGS194-04

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301049 | ALPHA | LAL | Thorium-228 | 1380 | | pCi/Kg | 180 |
| 301049 | ALPHA | LAL | Thorium-230 | 880 | | pCi/Kg | 130 |
| 301049 | ALPHA | LAL | Thorium-232 | 1120 | | pCi/Kg | 150 |
| 301049 | ALPHA | LAL | Uranium-233/234 | 1000 | | pCi/Kg | 140 |
| 301049 | ALPHA | LAL | Uranium-235 | 66 | | pCi/Kg | 34 |
| 301049 | ALPHA | LAL | Uranium-238 | 760 | | pCi/Kg | 120 |
| 301049 | BETA | LAL | Technetium-99 | 310 | | pCi/Kg | 210 |
| 301049 | GAMMA | LAL | Actinium-228 | 1040 | | pCi/Kg | |
| 301049 | GAMMA | LAL | Bismuth-212 | 500 | | pCi/Kg | |
| 301049 | GAMMA | LAL | Bismuth-214 | 740 | | pCi/Kg | |
| 301049 | GAMMA | LAL | Cesium-137 | -38 | | pCi/Kg | 20 |
| 301049 | GAMMA | LAL | Cobalt 60 | -1 | | pCi/Kg | |
| 301049 | GAMMA | LAL | Lead-210 | -800 | | pCi/Kg | |
| 301049 | GAMMA | LAL | Lead-212 | 940 | | pCi/Kg | |
| 301049 | GAMMA | LAL | Lead-214 | 1010 | | pCi/Kg | |
| 301049 | GAMMA | LAL | Potassium-40 | 3760 | | pCi/Kg | 720 |
| 301049 | GAMMA | LAL | Radium-223 | -220 | | pCi/Kg | |
| 301049 | GAMMA | LAL | Thallium-208 | 311 | | pCi/Kg | |
| 301049 | GAMMA | LAL | Thorium-234 | 670 | | pCi/Kg | 520 |
| 301049 | GAMMA | LAL | Uranium-235 | 100 | | pCi/Kg | 150 |
| 301049 | ICP-MS | LAL | Antimony | 0.19 | U | mg/Kg | |
| 301049 | ICP-MS | LAL | Beryllium | 0.49 | B | mg/Kg | |
| 301049 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301049 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301049 | ICP-MS | LAL | Thorium-232 | 6.4 | | mg/Kg | |
| 301049 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301049 | ICP-MS | LAL | Uranium-238 | 0.96 | | mg/Kg | |

# Background Soils Project Analytical Data

3/10/97

## Location BGS194-05

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301060 | ALPHA | LAL | Thorium-228 | 1080 | | pCi/Kg | 170 |
| 301060 | ALPHA | LAL | Thorium-230 | 750 | | pCi/Kg | 130 |
| 301060 | ALPHA | LAL | Thorium-232 | 1110 | | pCi/Kg | 160 |
| 301060 | ALPHA | LAL | Uranium-233/234 | 970 | B | pCi/Kg | 140 |
| 301060 | ALPHA | LAL | Uranium-235 | 53 | | pCi/Kg | 31 |
| 301060 | ALPHA | LAL | Uranium-238 | 850 | | pCi/Kg | 130 |
| 301060 | BETA | LAL | Technetium-99 | -136 | | pCi/Kg | 89 |
| 301060 | GAMMA | LAL | Actinium-228 | 980 | | pCi/Kg | |
| 301060 | GAMMA | LAL | Bismuth-214 | 710 | B | pCi/Kg | |
| 301060 | GAMMA | LAL | Cesium-134 | 20 | | pCi/Kg | 23 |
| 301060 | GAMMA | LAL | Cesium-137 | 14 | | pCi/Kg | 34 |
| 301060 | GAMMA | LAL | Cobalt 60 | -2 | | pCi/Kg | |
| 301060 | GAMMA | LAL | Cobalt-57 | -9 | | pCi/Kg | 14 |
| 301060 | GAMMA | LAL | Lead-212 | 990 | | pCi/Kg | |
| 301060 | GAMMA | LAL | Lead-214 | 860 | B | pCi/Kg | |
| 301060 | GAMMA | LAL | Potassium-40 | 7600 | | pCi/Kg | 1300 |
| 301060 | GAMMA | LAL | Thallium-208 | 296 | | pCi/Kg | |
| 301060 | GAMMA | LAL | Thorium-234 | 1100 | | pCi/Kg | 510 |
| 301060 | GAMMA | LAL | Uranium-235 | -20 | | pCi/Kg | 170 |
| 301060 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg | |
| 301060 | ICP-MS | LAL | Beryllium | 0.93 | B | mg/Kg | |
| 301060 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301060 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301060 | ICP-MS | LAL | Thorium-232 | 5.5 | | mg/Kg | |
| 301060 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301060 | ICP-MS | LAL | Uranium-238 | 1.3 | | mg/Kg | |
| 301060 | NAA | ORN | Thorium-232 | 7.4 | | mg/Kg | |
| 301060 | NAA | ORN | Uranium-235 | 0.017 | | mg/Kg | |
| 301060 | NAA | ORN | Uranium-238 | 1.9 | | mg/Kg | |
| 301060 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 53.63 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location BGS194-06

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301059 | ALPHA | LAL | Thorium-228 | 1050 | | pCi/Kg | 160 |
| 301059 | ALPHA | LAL | Thorium-230 | 930 | | pCi/Kg | 140 |
| 301059 | ALPHA | LAL | Thorium-232 | 1070 | | pCi/Kg | 150 |
| 301059 | ALPHA | LAL | Uranium-233/234 | 1380 | B | pCi/Kg | 200 |
| 301059 | ALPHA | LAL | Uranium-235 | 152 | F | pCi/Kg | 63 |
| 301059 | ALPHA | LAL | Uranium-238 | 1130 | F | pCi/Kg | 180 |
| 301059 | BETA | LAL | Technetium-99 | 560 | | pCi/Kg | 120 |
| 301059 | GAMMA | LAL | Actinium-228 | 1080 | | pCi/Kg | |
| 301059 | GAMMA | LAL | Bismuth-214 | 840 | B | pCi/Kg | |
| 301059 | GAMMA | LAL | Cesium-134 | 2 | | pCi/Kg | 24 |
| 301059 | GAMMA | LAL | Cesium-137 | -75 | | pCi/Kg | 40 |
| 301059 | GAMMA | LAL | Cobalt 60 | -20 | | pCi/Kg | |
| 301059 | GAMMA | LAL | Cobalt-57 | -9 | | pCi/Kg | 15 |
| 301059 | GAMMA | LAL | Lead-212 | 1020 | | pCi/Kg | |
| 301059 | GAMMA | LAL | Lead-214 | 1070 | B | pCi/Kg | |
| 301059 | GAMMA | LAL | Potassium-40 | 8700 | | pCi/Kg | 1400 |
| 301059 | GAMMA | LAL | Thallium-208 | 322 | | pCi/Kg | |
| 301059 | GAMMA | LAL | Thorium-234 | 1400 | | pCi/Kg | 1100 |
| 301059 | GAMMA | LAL | Uranium-235 | 130 | | pCi/Kg | 190 |
| 301059 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg | |
| 301059 | ICP-MS | LAL | Beryllium | 1.2 | | mg/Kg | |
| 301059 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301059 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301059 | ICP-MS | LAL | Thorium-232 | 5.6 | | mg/Kg | |
| 301059 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301059 | ICP-MS | LAL | Uranium-238 | 1.7 | | mg/Kg | |
| 301059 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 48.89 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location BGS196-02

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301061 | ALPHA | LAL | Thorium-228 | 1340 | | pCi/Kg | 160 |
| 301061 | ALPHA | LAL | Thorium-230 | 1110 | | pCi/Kg | 140 |
| 301061 | ALPHA | LAL | Thorium-232 | 1330 | | pCi/Kg | 160 |
| 301061 | ALPHA | LAL | Uranium-233/234 | 1080 | B | pCi/Kg | 150 |
| 301061 | ALPHA | LAL | Uranium-235 | 118 | | pCi/Kg | 48 |
| 301061 | ALPHA | LAL | Uranium-238 | 1000 | | pCi/Kg | 150 |
| 301061 | BETA | LAL | Technetium-99 | 530 | | pCi/Kg | 110 |
| 301061 | GAMMA | LAL | Actinium-228 | 1250 | | pCi/Kg | |
| 301061 | GAMMA | LAL | Bismuth-214 | 920 | B | pCi/Kg | |
| 301061 | GAMMA | LAL | Cesium-134 | 1 | | pCi/Kg | 14 |
| 301061 | GAMMA | LAL | Cesium-137 | -8 | | pCi/Kg | 19 |
| 301061 | GAMMA | LAL | Cobalt 60 | 15 | | pCi/Kg | |
| 301061 | GAMMA | LAL | Cobalt-57 | 9 | | pCi/Kg | 19 |
| 301061 | GAMMA | LAL | Lead-212 | 1200 | | pCi/Kg | |
| 301061 | GAMMA | LAL | Lead-214 | 1140 | B | pCi/Kg | |
| 301061 | GAMMA | LAL | Potassium-40 | 10300 | | pCi/Kg | 1300 |
| 301061 | GAMMA | LAL | Thallium-208 | 418 | | pCi/Kg | |
| 301061 | GAMMA | LAL | Thorium-234 | 700 | | pCi/Kg | 1100 |
| 301061 | GAMMA | LAL | Uranium-235 | 160 | | pCi/Kg | 130 |
| 301061 | ICP-MS | LAL | Antimony | 0.19 | U | mg/Kg | |
| 301061 | ICP-MS | LAL | Beryllium | 0.22 | B | mg/Kg | |
| 301061 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301061 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301061 | ICP-MS | LAL | Thorium-232 | 7.7 | | mg/Kg | |
| 301061 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301061 | ICP-MS | LAL | Uranium-238 | 0.91 | | mg/Kg | |
| 301061 | NAA | ORN | Thorium-232 | 10.6 | | mg/Kg | |
| 301061 | NAA | ORN | Uranium-235 | 0.02 | | mg/Kg | |
| 301061 | NAA | ORN | Uranium-238 | 2.59 | | mg/Kg | |
| 301061 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 34.57 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location BGS196-03

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301055 | ALPHA | LAL | Thorium-228 | 271 | | pCi/Kg | 86 |
| 301055 | ALPHA | LAL | Thorium-230 | 171 | | pCi/Kg | 56 |
| 301055 | ALPHA | LAL | Thorium-232 | 268 | | pCi/Kg | 69 |
| 301055 | ALPHA | LAL | Uranium-233/234 | 233 | B | pCi/Kg | 65 |
| 301055 | ALPHA | LAL | Uranium-235 | 25 | | pCi/Kg | 22 |
| 301055 | ALPHA | LAL | Uranium-238 | 145 | | pCi/Kg | 51 |
| 301055 | BETA | LAL | Technetium-99 | 129 | | pCi/Kg | 93 |
| 301055 | GAMMA | LAL | Actinium-228 | 136 | | pCi/Kg | |
| 301055 | GAMMA | LAL | Bismuth-214 | 200 | B | pCi/Kg | |
| 301055 | GAMMA | LAL | Cesium-134 | 3 | | pCi/Kg | 15 |
| 301055 | GAMMA | LAL | Cesium-137 | -9 | | pCi/Kg | 22 |
| 301055 | GAMMA | LAL | Cobalt 60 | 0 | | pCi/Kg | |
| 301055 | GAMMA | LAL | Cobalt-57 | 1 | | pCi/Kg | 14 |
| 301055 | GAMMA | LAL | Lead-212 | 314 | | pCi/Kg | |
| 301055 | GAMMA | LAL | Lead-214 | 216 | B | pCi/Kg | |
| 301055 | GAMMA | LAL | Potassium-40 | 510 | | pCi/Kg | 360 |
| 301055 | GAMMA | LAL | Thallium-208 | 62 | | pCi/Kg | |
| 301055 | GAMMA | LAL | Thorium-234 | 190 | | pCi/Kg | 300 |
| 301055 | GAMMA | LAL | Uranium-235 | 80 | | pCi/Kg | 110 |
| 301055 | ICP-MS | LAL | Antimony | 0.19 | U | mg/Kg | |
| 301055 | ICP-MS | LAL | Beryllium | 0.19 | U | mg/Kg | |
| 301055 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301055 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301055 | ICP-MS | LAL | Thorium-232 | 2 | | mg/Kg | |
| 301055 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301055 | ICP-MS | LAL | Uranium-238 | 0.25 | | mg/Kg | |
| 301055 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 5.22 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location BGS196-04

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301054 | ALPHA | LAL | Thorium-228 | 400 | | pCi/Kg | 110 |
| 301054 | ALPHA | LAL | Thorium-230 | 278 | | pCi/Kg | 73 |
| 301054 | ALPHA | LAL | Thorium-232 | 428 | | pCi/Kg | 91 |
| 301054 | ALPHA | LAL | Uranium-233/234 | 334 | B | pCi/Kg | 79 |
| 301054 | ALPHA | LAL | Uranium-235 | 32 | | pCi/Kg | 24 |
| 301054 | ALPHA | LAL | Uranium-238 | 290 | | pCi/Kg | 72 |
| 301054 | BETA | LAL | Technetium-99 | -138 | | pCi/Kg | 100 |
| 301054 | GAMMA | LAL | Actinium-228 | 459 | | pCi/Kg | |
| 301054 | GAMMA | LAL | Bismuth-214 | 279 | B | pCi/Kg | |
| 301054 | GAMMA | LAL | Cesium-134 | 7.4 | | pCi/Kg | 10 |
| 301054 | GAMMA | LAL | Cesium-137 | 10 | | pCi/Kg | 13 |
| 301054 | GAMMA | LAL | Cobalt 60 | -9.8 | | pCi/Kg | |
| 301054 | GAMMA | LAL | Cobalt-57 | -2 | | pCi/Kg | 8.3 |
| 301054 | GAMMA | LAL | Lead-212 | 461 | | pCi/Kg | |
| 301054 | GAMMA | LAL | Lead-214 | 342 | B | pCi/Kg | |
| 301054 | GAMMA | LAL | Potassium-40 | 2140 | | pCi/Kg | 430 |
| 301054 | GAMMA | LAL | Thallium-208 | 140 | | pCi/Kg | |
| 301054 | GAMMA | LAL | Thorium-234 | 230 | | pCi/Kg | 330 |
| 301054 | GAMMA | LAL | Uranium-235 | 59 | | pCi/Kg | 94 |
| 301054 | ICP-MS | LAL | Antimony | 0.19 | U | mg/Kg | |
| 301054 | ICP-MS | LAL | Beryllium | 0.19 | U | mg/Kg | |
| 301054 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301054 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301054 | ICP-MS | LAL | Thorium-232 | 2.4 | | mg/Kg | |
| 301054 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301054 | ICP-MS | LAL | Uranium-238 | 0.2 | | mg/Kg | |
| 301054 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 15.8 | | % | |
| 301056 | ALPHA | LAL | Thorium-228 | 209 | | pCi/Kg | 89 |
| 301056 | ALPHA | LAL | Thorium-230 | 70 | | pCi/Kg | 42 |
| 301056 | ALPHA | LAL | Thorium-232 | 174 | | pCi/Kg | 59 |
| 301056 | ALPHA | LAL | Uranium-233/234 | 125 | B | pCi/Kg | 53 |
| 301056 | ALPHA | LAL | Uranium-235 | 27 | | pCi/Kg | 23 |
| 301056 | ALPHA | LAL | Uranium-238 | 175 | | pCi/Kg | 58 |
| 301056 | BETA | LAL | Technetium-99 | -60 | | pCi/Kg | 95 |
| 301056 | GAMMA | LAL | Actinium-228 | 260 | | pCi/Kg | |
| 301056 | GAMMA | LAL | Bismuth-214 | 172 | B | pCi/Kg | |
| 301056 | GAMMA | LAL | Cesium-134 | 0 | | pCi/Kg | 13 |
| 301056 | GAMMA | LAL | Cesium-137 | 0 | | pCi/Kg | 20 |
| 301056 | GAMMA | LAL | Cobalt 60 | -12 | | pCi/Kg | |
| 301056 | GAMMA | LAL | Cobalt-57 | -8.7 | | pCi/Kg | 8.5 |
| 301056 | GAMMA | LAL | Lead-212 | 238 | | pCi/Kg | |
| 301056 | GAMMA | LAL | Lead-214 | 166 | B | pCi/Kg | |
| 301056 | GAMMA | LAL | Potassium-40 | 1280 | | pCi/Kg | 470 |
| 301056 | GAMMA | LAL | Thallium-208 | 69 | | pCi/Kg | |
| 301056 | GAMMA | LAL | Thorium-234 | 460 | | pCi/Kg | 320 |
| 301056 | GAMMA | LAL | Uranium-235 | 10 | | pCi/Kg | 110 |

# Background Soils Project Analytical Data

3/10/97

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|---|---|---|---|---|---|---|
| 301056 | ICP-MS | LAL | Antimony | 0.2 | U | mg/Kg |
| 301056 | ICP-MS | LAL | Beryllium | 0.2 | U | mg/Kg |
| 301056 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg |
| 301056 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg |
| 301056 | ICP-MS | LAL | Thorium-232 | 1 | | mg/Kg |
| 301056 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg |
| 301056 | ICP-MS | LAL | Uranium-238 | 0.2 | U | mg/Kg |
| 301056 | NAA | ORN | Thorium-232 | 1.86 | | mg/Kg |
| 301056 | NAA | ORN | Uranium-235 | 0.003 | | mg/Kg |
| 301056 | NAA | ORN | Uranium-238 | 0.45 | | mg/Kg |
| 301056 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 3.56 | | % |

# Background Soils Project Analytical Data

3/10/97

## Location C01,10,24

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301017 | ALPHA | LAL | Neptunium-237 | 15 | | pCi/Kg | 13 |
| 301017 | ALPHA | LAL | Plutonium-238 | 0.8 | | pCi/Kg | 1.5 |
| 301017 | ALPHA | LAL | Plutonium-239/240 | 7 | | pCi/Kg | 4.6 |
| 301017 | ALPHA | LAL | Thorium-228 | 1250 | | pCi/Kg | 170 |
| 301017 | ALPHA | LAL | Thorium-230 | 1260 | | pCi/Kg | 160 |
| 301017 | ALPHA | LAL | Thorium-232 | 1110 | | pCi/Kg | 150 |
| 301017 | ALPHA | LAL | Uranium-233/234 | 950 | | pCi/Kg | 98 |
| 301017 | ALPHA | LAL | Uranium-235 | 63 | | pCi/Kg | 23 |
| 301017 | ALPHA | LAL | Uranium-238 | 950 | | pCi/Kg | 98 |
| 301017 | BETA | LAL | Strontium-90 | 130 | | pCi/Kg | |
| 301017 | BETA | LAL | Technetium-99 | 110 | | pCi/Kg | 180 |
| 301017 | GAMMA | LAL | Actinium-228 | 1210 | | pCi/Kg | |
| 301017 | GAMMA | LAL | Bismuth-212 | 760 | | pCi/Kg | |
| 301017 | GAMMA | LAL | Bismuth-214 | 1200 | | pCi/Kg | |
| 301017 | GAMMA | LAL | Cesium-137 | 226 | | pCi/Kg | 65 |
| 301017 | GAMMA | LAL | Cobalt 60 | -5 | | pCi/Kg | |
| 301017 | GAMMA | LAL | Lead-210 | 2300 | | pCi/Kg | |
| 301017 | GAMMA | LAL | Lead-212 | 1250 | | pCi/Kg | |
| 301017 | GAMMA | LAL | Lead-214 | 1560 | | pCi/Kg | |
| 301017 | GAMMA | LAL | Potassium-40 | 13700 | | pCi/Kg | 1900 |
| 301017 | GAMMA | LAL | Radium-223 | -130 | | pCi/Kg | |
| 301017 | GAMMA | LAL | Thallium-208 | 366 | | pCi/Kg | |
| 301017 | GAMMA | LAL | Thorium-234 | 2050 | | pCi/Kg | 530 |
| 301017 | GAMMA | LAL | Uranium-235 | 120 | | pCi/Kg | 180 |
| 301017 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301017 | ICP-MS | LAL | Beryllium | 0.55 | B | mg/Kg | |
| 301017 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301017 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301017 | ICP-MS | LAL | Thorium-232 | 4.8 | | mg/Kg | |
| 301017 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301017 | ICP-MS | LAL | Uranium-238 | 1.1 | | mg/Kg | |
| 301017 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 9.49 | | % | |
| 301018 | ALPHA | LAL | Thorium-228 | 1300 | | pCi/Kg | 160 |
| 301018 | ALPHA | LAL | Thorium-230 | 1190 | | pCi/Kg | 140 |
| 301018 | ALPHA | LAL | Thorium-232 | 1230 | | pCi/Kg | 140 |
| 301018 | ALPHA | LAL | Uranium-233/234 | 966 | | pCi/Kg | 83 |
| 301018 | ALPHA | LAL | Uranium-235 | 60 | | pCi/Kg | 17 |
| 301018 | ALPHA | LAL | Uranium-238 | 1033 | | pCi/Kg | 87 |
| 301018 | BETA | LAL | Technetium-99 | 30 | | pCi/Kg | 180 |
| 301018 | GAMMA | LAL | Actinium-228 | 1470 | | pCi/Kg | |
| 301018 | GAMMA | LAL | Bismuth-212 | 760 | | pCi/Kg | |
| 301018 | GAMMA | LAL | Bismuth-214 | 1180 | | pCi/Kg | |
| 301018 | GAMMA | LAL | Cesium-137 | -13 | | pCi/Kg | 21 |
| 301018 | GAMMA | LAL | Cobalt 60 | -4 | | pCi/Kg | |
| 301018 | GAMMA | LAL | Lead-210 | 200 | | pCi/Kg | |
| 301018 | GAMMA | LAL | Lead-212 | 1330 | | pCi/Kg | |

# Background Soils Project Analytical Data

3/10/97

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|---|---|---|---|---|---|---|---|
| 301018 | GAMMA | LAL | Lead-214 | 1520 | | pCi/Kg | |
| 301018 | GAMMA | LAL | Potassium-40 | 14200 | | pCi/Kg | 1700 |
| 301018 | GAMMA | LAL | Radium-223 | 100 | | pCi/Kg | |
| 301018 | GAMMA | LAL | Thallium-208 | 390 | | pCi/Kg | |
| 301018 | GAMMA | LAL | Thorium-234 | 1060 | | pCi/Kg | 480 |
| 301018 | GAMMA | LAL | Uranium-235 | -30 | | pCi/Kg | 130 |
| 301018 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301018 | ICP-MS | LAL | Beryllium | 0.46 | B | mg/Kg | |
| 301018 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301018 | ICP-MS | LAL | Thallium | 0.3 | B | mg/Kg | |
| 301018 | ICP-MS | LAL | Thorium-232 | 6.9 | | mg/Kg | |
| 301018 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301018 | ICP-MS | LAL | Uranium-238 | 1.2 | | mg/Kg | |
| 301018 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 25.85 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location C02,03,20

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301019 | ALPHA | LAL | Neptunium-237 | 18 | | pCi/Kg | 17 |
| 301019 | ALPHA | LAL | Plutonium-238 | 2.3 | | pCi/Kg | 3.3 |
| 301019 | ALPHA | LAL | Plutonium-239/240 | 9 | | pCi/Kg | 5.1 |
| 301019 | ALPHA | LAL | Thorium-228 | 1220 | | pCi/Kg | 160 |
| 301019 | ALPHA | LAL | Thorium-230 | 1230 | | pCi/Kg | 150 |
| 301019 | ALPHA | LAL | Thorium-232 | 1280 | | pCi/Kg | 150 |
| 301019 | ALPHA | LAL | Uranium-233/234 | 958 | | pCi/Kg | 96 |
| 301019 | ALPHA | LAL | Uranium-235 | 22 | | pCi/Kg | 14 |
| 301019 | ALPHA | LAL | Uranium-238 | 1026 | | pCi/Kg | 100 |
| 301019 | BETA | LAL | Strontium-90 | -280 | | pCi/Kg | |
| 301019 | BETA | LAL | Technetium-99 | 440 | | pCi/Kg | 210 |
| 301019 | GAMMA | LAL | Actinium-228 | 1170 | | pCi/Kg | |
| 301019 | GAMMA | LAL | Bismuth-212 | 690 | | pCi/Kg | |
| 301019 | GAMMA | LAL | Bismuth-214 | 1030 | | pCi/Kg | |
| 301019 | GAMMA | LAL | Cesium-137 | 104 | | pCi/Kg | 27 |
| 301019 | GAMMA | LAL | Cobalt 60 | -1 | | pCi/Kg | |
| 301019 | GAMMA | LAL | Lead-210 | 1800 | | pCi/Kg | |
| 301019 | GAMMA | LAL | Lead-212 | 1030 | | pCi/Kg | |
| 301019 | GAMMA | LAL | Lead-214 | 1250 | | pCi/Kg | |
| 301019 | GAMMA | LAL | Potassium-40 | 13100 | | pCi/Kg | 1500 |
| 301019 | GAMMA | LAL | Radium-223 | 10 | | pCi/Kg | |
| 301019 | GAMMA | LAL | Thallium-208 | 361 | | pCi/Kg | |
| 301019 | GAMMA | LAL | Thorium-234 | 980 | | pCi/Kg | 430 |
| 301019 | GAMMA | LAL | Uranium-235 | -40 | | pCi/Kg | 110 |
| 301019 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301019 | ICP-MS | LAL | Beryllium | 0.54 | B | mg/Kg | |
| 301019 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301019 | ICP-MS | LAL | Thallium | 0.19 | B | mg/Kg | |
| 301019 | ICP-MS | LAL | Thorium-232 | 6 | | mg/Kg | |
| 301019 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301019 | ICP-MS | LAL | Uranium-238 | 1.3 | | mg/Kg | |
| 301019 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 14.66 | | % | |
| 301020 | ALPHA | LAL | Thorium-228 | 1220 | | pCi/Kg | 160 |
| 301020 | ALPHA | LAL | Thorium-230 | 1390 | | pCi/Kg | 160 |
| 301020 | ALPHA | LAL | Thorium-232 | 1280 | | pCi/Kg | 150 |
| 301020 | ALPHA | LAL | Uranium-233/234 | 931 | | pCi/Kg | 84 |
| 301020 | ALPHA | LAL | Uranium-235 | 48 | | pCi/Kg | 16 |
| 301020 | ALPHA | LAL | Uranium-238 | 1001 | | pCi/Kg | 88 |
| 301020 | BETA | LAL | Technetium-99 | 60 | | pCi/Kg | 190 |
| 301020 | GAMMA | LAL | Actinium-228 | 1400 | | pCi/Kg | |
| 301020 | GAMMA | LAL | Bismuth-212 | 910 | | pCi/Kg | |
| 301020 | GAMMA | LAL | Bismuth-214 | 1230 | | pCi/Kg | |
| 301020 | GAMMA | LAL | Cesium-137 | -13 | | pCi/Kg | 39 |
| 301020 | GAMMA | LAL | Cobalt 60 | -21 | | pCi/Kg | |
| 301020 | GAMMA | LAL | Lead-210 | 1590 | | pCi/Kg | |
| 301020 | GAMMA | LAL | Lead-212 | 1430 | | pCi/Kg | |

# Background Soils Project Analytical Data

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 301020 | GAMMA | LAL | Lead-214 | 1450 | | pCi/Kg | |
| 301020 | GAMMA | LAL | Potassium-40 | 14900 | | pCi/Kg | 2000 |
| 301020 | GAMMA | LAL | Radium-223 | -160 | | pCi/Kg | |
| 301020 | GAMMA | LAL | Thallium-208 | 457 | | pCi/Kg | |
| 301020 | GAMMA | LAL | Thorium-234 | 1560 | | pCi/Kg | 490 |
| 301020 | GAMMA | LAL | Uranium-235 | -120 | | pCi/Kg | 130 |
| 301020 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301020 | ICP-MS | LAL | Beryllium | 0.52 | B | mg/Kg | |
| 301020 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301020 | ICP-MS | LAL | Thallium | 0.29 | B | mg/Kg | |
| 301020 | ICP-MS | LAL | Thorium-232 | 7 | | mg/Kg | |
| 301020 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301020 | ICP-MS | LAL | Uranium-238 | 1.3 | | mg/Kg | |
| 301020 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 22.44 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location C07,08,09

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301013 | ALPHA | LAL | Neptunium-237 | 22 | | pCi/Kg | 21 |
| 301013 | ALPHA | LAL | Plutonium-238 | 0.8 | | pCi/Kg | 3.5 |
| 301013 | ALPHA | LAL | Plutonium-239/240 | 11.3 | | pCi/Kg | 5.9 |
| 301013 | ALPHA | LAL | Thorium-228 | 1250 | | pCi/Kg | 170 |
| 301013 | ALPHA | LAL | Thorium-230 | 1100 | | pCi/Kg | 150 |
| 301013 | ALPHA | LAL | Thorium-232 | 1160 | | pCi/Kg | 150 |
| 301013 | ALPHA | LAL | Uranium-233/234 | 817 | | pCi/Kg | 80 |
| 301013 | ALPHA | LAL | Uranium-235 | 53 | | pCi/Kg | 18 |
| 301013 | ALPHA | LAL | Uranium-238 | 1035 | | pCi/Kg | 93 |
| 301013 | BETA | LAL | Strontium-90 | 190 | | pCi/Kg | |
| 301013 | BETA | LAL | Technetium-99 | 280 | | pCi/Kg | 200 |
| 301013 | GAMMA | LAL | Actinium-228 | 1230 | | pCi/Kg | |
| 301013 | GAMMA | LAL | Bismuth-212 | 790 | | pCi/Kg | |
| 301013 | GAMMA | LAL | Bismuth-214 | 1030 | | pCi/Kg | |
| 301013 | GAMMA | LAL | Cesium-137 | 250 | | pCi/Kg | 43 |
| 301013 | GAMMA | LAL | Cobalt 60 | -4 | | pCi/Kg | |
| 301013 | GAMMA | LAL | Lead-210 | 2700 | | pCi/Kg | |
| 301013 | GAMMA | LAL | Lead-212 | 1160 | | pCi/Kg | |
| 301013 | GAMMA | LAL | Lead-214 | 1380 | | pCi/Kg | |
| 301013 | GAMMA | LAL | Potassium-40 | 14300 | | pCi/Kg | 1700 |
| 301013 | GAMMA | LAL | Radium-223 | 160 | | pCi/Kg | |
| 301013 | GAMMA | LAL | Thallium-208 | 372 | | pCi/Kg | |
| 301013 | GAMMA | LAL | Thorium-234 | 950 | | pCi/Kg | 500 |
| 301013 | GAMMA | LAL | Uranium-235 | 60 | | pCi/Kg | 140 |
| 301013 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301013 | ICP-MS | LAL | Beryllium | 0.34 | B | mg/Kg | |
| 301013 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301013 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301013 | ICP-MS | LAL | Thorium-232 | 4.9 | | mg/Kg | |
| 301013 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301013 | ICP-MS | LAL | Uranium-238 | 0.96 | | mg/Kg | |
| 301013 | NAA | ORN | Thorium-232 | 8.8 | | mg/Kg | |
| 301013 | NAA | ORN | Uranium-235 | 0.023 | | mg/Kg | |
| 301013 | NAA | ORN | Uranium-238 | 3.3 | | mg/Kg | |
| 301013 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 11.15 | | % | |
| 301014 | ALPHA | LAL | Thorium-228 | 1260 | | pCi/Kg | 150 |
| 301014 | ALPHA | LAL | Thorium-230 | 1320 | | pCi/Kg | 150 |
| 301014 | ALPHA | LAL | Thorium-232 | 1190 | | pCi/Kg | 140 |
| 301014 | ALPHA | LAL | Uranium-233/234 | 953 | | pCi/Kg | 86 |
| 301014 | ALPHA | LAL | Uranium-235 | 50 | | pCi/Kg | 17 |
| 301014 | ALPHA | LAL | Uranium-238 | 936 | | pCi/Kg | 84 |
| 301014 | BETA | LAL | Technetium-99 | 410 | | pCi/Kg | 200 |
| 301014 | GAMMA | LAL | Actinium-228 | 1370 | | pCi/Kg | |
| 301014 | GAMMA | LAL | Bismuth-212 | 680 | | pCi/Kg | |
| 301014 | GAMMA | LAL | Bismuth-214 | 1320 | | pCi/Kg | |
| 301014 | GAMMA | LAL | Cesium-137 | -25 | | pCi/Kg | 33 |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301014 | GAMMA | LAL | Cobalt 60 | -21 | | pCi/Kg | |
| 301014 | GAMMA | LAL | Lead-210 | 1560 | | pCi/Kg | |
| 301014 | GAMMA | LAL | Lead-212 | 1470 | | pCi/Kg | |
| 301014 | GAMMA | LAL | Lead-214 | 1540 | | pCi/Kg | |
| 301014 | GAMMA | LAL | Potassium-40 | 15500 | | pCi/Kg | 2000 |
| 301014 | GAMMA | LAL | Radium-223 | -50 | | pCi/Kg | |
| 301014 | GAMMA | LAL | Thallium-208 | 438 | | pCi/Kg | |
| 301014 | GAMMA | LAL | Thorium-234 | 1310 | | pCi/Kg | 470 |
| 301014 | GAMMA | LAL | Uranium-235 | 150 | | pCi/Kg | 160 |
| 301014 | ICP-MS | LAL | Antimony | 0.21 | UN | mg/Kg | |
| 301014 | ICP-MS | LAL | Beryllium | 0.46 | B | mg/Kg | |
| 301014 | ICP-MS | LAL | Cadmium | 0.21 | U | mg/Kg | |
| 301014 | ICP-MS | LAL | Thallium | 0.28 | B | mg/Kg | |
| 301014 | ICP-MS | LAL | Thorium-232 | 7.1 | | mg/Kg | |
| 301014 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301014 | ICP-MS | LAL | Uranium-238 | 1.2 | | mg/Kg | |
| 301014 | NAA | ORN | Thorium-232 | 10.1 | | mg/Kg | |
| 301014 | NAA | ORN | Uranium-235 | 0.023 | | mg/Kg | |
| 301014 | NAA | ORN | Uranium-238 | 3.1 | | mg/Kg | |
| 301014 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 24.26 | | % | |
| 301015 | ALPHA | LAL | Neptunium-237 | 5 | | pCi/Kg | 15 |
| 301015 | ALPHA | LAL | Plutonium-238 | 5.6 | | pCi/Kg | 4.1 |
| 301015 | ALPHA | LAL | Plutonium-239/240 | 7.2 | | pCi/Kg | 6.1 |
| 301015 | ALPHA | LAL | Thorium-228 | 1230 | | pCi/Kg | 170 |
| 301015 | ALPHA | LAL | Thorium-230 | 1110 | | pCi/Kg | 150 |
| 301015 | ALPHA | LAL | Thorium-232 | 1140 | | pCi/Kg | 150 |
| 301015 | ALPHA | LAL | Uranium-233/234 | 916 | F | pCi/Kg | 94 |
| 301015 | ALPHA | LAL | Uranium-235 | 92 | F | pCi/Kg | 27 |
| 301015 | ALPHA | LAL | Uranium-238 | 996 | F | pCi/Kg | 99 |
| 301015 | BETA | LAL | Strontium-90 | -230 | | pCi/Kg | |
| 301015 | BETA | LAL | Technetium-99 | 10 | | pCi/Kg | 170 |
| 301015 | GAMMA | LAL | Actinium-228 | 1100 | | pCi/Kg | |
| 301015 | GAMMA | LAL | Bismuth-212 | 810 | | pCi/Kg | |
| 301015 | GAMMA | LAL | Bismuth-214 | 1190 | | pCi/Kg | |
| 301015 | GAMMA | LAL | Cesium-137 | 189 | | pCi/Kg | 48 |
| 301015 | GAMMA | LAL | Cobalt 60 | -4 | | pCi/Kg | |
| 301015 | GAMMA | LAL | Lead-210 | 2090 | | pCi/Kg | |
| 301015 | GAMMA | LAL | Lead-212 | 1280 | | pCi/Kg | |
| 301015 | GAMMA | LAL | Lead-214 | 1420 | | pCi/Kg | |
| 301015 | GAMMA | LAL | Potassium-40 | 14300 | | pCi/Kg | 1900 |
| 301015 | GAMMA | LAL | Radium-223 | -190 | | pCi/Kg | |
| 301015 | GAMMA | LAL | Thallium-208 | 362 | | pCi/Kg | |
| 301015 | GAMMA | LAL | Thorium-234 | 1610 | | pCi/Kg | 450 |
| 301015 | GAMMA | LAL | Uranium-235 | 60 | | pCi/Kg | 150 |
| 301015 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301015 | ICP-MS | LAL | Beryllium | 0.44 | B | mg/Kg | |
| 301015 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301015 | ICP-MS | LAL | Thallium | 0.2 | B | mg/Kg | |
| 301015 | ICP-MS | LAL | Thorium-232 | 5.5 | | mg/Kg | |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301015 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301015 | ICP-MS | LAL | Uranium-238 | 1.3 | | mg/Kg | |
| 301015 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 11.72 | | % | |
| 301016 | ALPHA | LAL | Thorium-228 | 1240 | | pCi/Kg | 150 |
| 301016 | ALPHA | LAL | Thorium-230 | 1220 | | pCi/Kg | 140 |
| 301016 | ALPHA | LAL | Thorium-232 | 1100 | | pCi/Kg | 130 |
| 301016 | ALPHA | LAL | Uranium-233/234 | 809 | | pCi/Kg | 75 |
| 301016 | ALPHA | LAL | Uranium-235 | 30 | | pCi/Kg | 12 |
| 301016 | ALPHA | LAL | Uranium-238 | 905 | | pCi/Kg | 80 |
| 301016 | BETA | LAL | Technetium-99 | 170 | | pCi/Kg | 190 |
| 301016 | GAMMA | LAL | Actinium-228 | 1310 | | pCi/Kg | |
| 301016 | GAMMA | LAL | Bismuth-212 | 580 | | pCi/Kg | |
| 301016 | GAMMA | LAL | Bismuth-214 | 1200 | | pCi/Kg | |
| 301016 | GAMMA | LAL | Cesium-137 | 20 | | pCi/Kg | 40 |
| 301016 | GAMMA | LAL | Cobalt 60 | 17 | | pCi/Kg | |
| 301016 | GAMMA | LAL | Lead-210 | 1510 | | pCi/Kg | |
| 301016 | GAMMA | LAL | Lead-212 | 1350 | | pCi/Kg | |
| 301016 | GAMMA | LAL | Lead-214 | 1430 | | pCi/Kg | |
| 301016 | GAMMA | LAL | Potassium-40 | 14700 | | pCi/Kg | 1900 |
| 301016 | GAMMA | LAL | Radium-223 | 180 | | pCi/Kg | |
| 301016 | GAMMA | LAL | Thallium-208 | 425 | | pCi/Kg | |
| 301016 | GAMMA | LAL | Thorium-234 | 1730 | | pCi/Kg | 490 |
| 301016 | GAMMA | LAL | Uranium-235 | 100 | | pCi/Kg | 170 |
| 301016 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301016 | ICP-MS | LAL | Beryllium | 0.46 | B | mg/Kg | |
| 301016 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301016 | ICP-MS | LAL | Thallium | 0.27 | B | mg/Kg | |
| 301016 | ICP-MS | LAL | Thorium-232 | 7 | | mg/Kg | |
| 301016 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301016 | ICP-MS | LAL | Uranium-238 | 1.2 | | mg/Kg | |
| 301016 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 26.86 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location C12,18,19

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301011 | ALPHA | LAL | Neptunium-237 | 12 | | pCi/Kg | 12 |
| 301011 | ALPHA | LAL | Plutonium-238 | 3.2 | | pCi/Kg | 3.8 |
| 301011 | ALPHA | LAL | Plutonium-239/240 | 10.3 | | pCi/Kg | 5.6 |
| 301011 | ALPHA | LAL | Thorium-228 | 1130 | | pCi/Kg | 160 |
| 301011 | ALPHA | LAL | Thorium-230 | 1200 | | pCi/Kg | 150 |
| 301011 | ALPHA | LAL | Thorium-232 | 1050 | | pCi/Kg | 140 |
| 301011 | ALPHA | LAL | Uranium-233/234 | 1020 | | pCi/Kg | 94 |
| 301011 | ALPHA | LAL | Uranium-235 | 71 | | pCi/Kg | 21 |
| 301011 | ALPHA | LAL | Uranium-238 | 1058 | | pCi/Kg | 96 |
| 301011 | BETA | LAL | Strontium-90 | 50 | | pCi/Kg | |
| 301011 | BETA | LAL | Technetium-99 | 120 | | pCi/Kg | 190 |
| 301011 | GAMMA | LAL | Actinium-228 | 1200 | | pCi/Kg | |
| 301011 | GAMMA | LAL | Bismuth-212 | 760 | | pCi/Kg | |
| 301011 | GAMMA | LAL | Bismuth-214 | 1170 | | pCi/Kg | |
| 301011 | GAMMA | LAL | Cesium-137 | 161 | | pCi/Kg | 59 |
| 301011 | GAMMA | LAL | Cobalt 60 | 6 | | pCi/Kg | |
| 301011 | GAMMA | LAL | Lead-210 | 2400 | | pCi/Kg | |
| 301011 | GAMMA | LAL | Lead-212 | 1260 | | pCi/Kg | |
| 301011 | GAMMA | LAL | Lead-214 | 1390 | | pCi/Kg | |
| 301011 | GAMMA | LAL | Potassium-40 | 13100 | | pCi/Kg | 1800 |
| 301011 | GAMMA | LAL | Radium-223 | 10 | | pCi/Kg | |
| 301011 | GAMMA | LAL | Thallium-208 | 411 | | pCi/Kg | |
| 301011 | GAMMA | LAL | Thorium-234 | 1960 | | pCi/Kg | 520 |
| 301011 | GAMMA | LAL | Uranium-235 | 80 | | pCi/Kg | 160 |
| 301011 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301011 | ICP-MS | LAL | Beryllium | 0.47 | B | mg/Kg | |
| 301011 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301011 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301011 | ICP-MS | LAL | Thorium-232 | 5.1 | | mg/Kg | |
| 301011 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301011 | ICP-MS | LAL | Uranium-238 | 1.1 | | mg/Kg | |
| 301011 | NAA | ORN | Thorium-232 | 7.6 | | mg/Kg | |
| 301011 | NAA | ORN | Uranium-235 | 0.023 | | mg/Kg | |
| 301011 | NAA | ORN | Uranium-238 | 3.2 | | mg/Kg | |
| 301011 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 9.38 | | % | |
| 301012 | ALPHA | LAL | Thorium-228 | 1180 | | pCi/Kg | 150 |
| 301012 | ALPHA | LAL | Thorium-230 | 1130 | | pCi/Kg | 140 |
| 301012 | ALPHA | LAL | Thorium-232 | 1160 | | pCi/Kg | 140 |
| 301012 | ALPHA | LAL | Uranium-233/234 | 910 | | pCi/Kg | 84 |
| 301012 | ALPHA | LAL | Uranium-235 | 55 | | pCi/Kg | 18 |
| 301012 | ALPHA | LAL | Uranium-238 | 971 | | pCi/Kg | 87 |
| 301012 | BETA | LAL | Technetium-99 | 0 | | pCi/Kg | 170 |
| 301012 | GAMMA | LAL | Actinium-228 | 1250 | | pCi/Kg | |
| 301012 | GAMMA | LAL | Bismuth-212 | 820 | | pCi/Kg | |
| 301012 | GAMMA | LAL | Bismuth-214 | 1070 | | pCi/Kg | |
| 301012 | GAMMA | LAL | Cesium-137 | 1 | | pCi/Kg | 20 |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301012 | GAMMA | LAL | Cobalt 60 | -10 | | pCi/Kg | |
| 301012 | GAMMA | LAL | Lead-210 | 3200 | | pCi/Kg | |
| 301012 | GAMMA | LAL | Lead-212 | 1170 | | pCi/Kg | |
| 301012 | GAMMA | LAL | Lead-214 | 1370 | | pCi/Kg | |
| 301012 | GAMMA | LAL | Potassium-40 | 12400 | | pCi/Kg | 1500 |
| 301012 | GAMMA | LAL | Radium-223 | 0 | | pCi/Kg | |
| 301012 | GAMMA | LAL | Thallium-208 | 398 | | pCi/Kg | |
| 301012 | GAMMA | LAL | Thorium-234 | 1240 | | pCi/Kg | 470 |
| 301012 | GAMMA | LAL | Uranium-235 | 20 | | pCi/Kg | 140 |
| 301012 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301012 | ICP-MS | LAL | Beryllium | 0.38 | B | mg/Kg | |
| 301012 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301012 | ICP-MS | LAL | Thallium | 0.21 | B | mg/Kg | |
| 301012 | ICP-MS | LAL | Thorium-232 | 6.2 | | mg/Kg | |
| 301012 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301012 | ICP-MS | LAL | Uranium-238 | 0.94 | | mg/Kg | |
| 301012 | NAA | ORN | Thorium-232 | 10 | | mg/Kg | |
| 301012 | NAA | ORN | Uranium-235 | 0.021 | | mg/Kg | |
| 301012 | NAA | ORN | Uranium-238 | 2.9 | | mg/Kg | |
| 301012 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 19.85 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location F01,21,23

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301009 | ALPHA | LAL | Neptunium-237 | 11 | | pCi/Kg | 15 |
| 301009 | ALPHA | LAL | Plutonium-238 | 1.6 | | pCi/Kg | 4.5 |
| 301009 | ALPHA | LAL | Plutonium-239/240 | 4.8 | | pCi/Kg | 5.5 |
| 301009 | ALPHA | LAL | Thorium-228 | 1120 | | pCi/Kg | 150 |
| 301009 | ALPHA | LAL | Thorium-230 | 1030 | | pCi/Kg | 130 |
| 301009 | ALPHA | LAL | Thorium-232 | 1080 | | pCi/Kg | 140 |
| 301009 | ALPHA | LAL | Uranium-233/234 | 870 | | pCi/Kg | 80 |
| 301009 | ALPHA | LAL | Uranium-235 | 64 | | pCi/Kg | 19 |
| 301009 | ALPHA | LAL | Uranium-238 | 923 | | pCi/Kg | 83 |
| 301009 | BETA | LAL | Strontium-90 | -50 | | pCi/Kg | |
| 301009 | BETA | LAL | Technetium-99 | 40 | | pCi/Kg | 180 |
| 301009 | GAMMA | LAL | Actinium-228 | 1000 | | pCi/Kg | |
| 301009 | GAMMA | LAL | Bismuth-212 | 810 | | pCi/Kg | |
| 301009 | GAMMA | LAL | Bismuth-214 | 1120 | | pCi/Kg | |
| 301009 | GAMMA | LAL | Cesium-137 | 194 | | pCi/Kg | 67 |
| 301009 | GAMMA | LAL | Cobalt 60 | -6 | | pCi/Kg | |
| 301009 | GAMMA | LAL | Lead-210 | 1600 | | pCi/Kg | |
| 301009 | GAMMA | LAL | Lead-212 | 1140 | | pCi/Kg | |
| 301009 | GAMMA | LAL | Lead-214 | 1240 | | pCi/Kg | |
| 301009 | GAMMA | LAL | Potassium-40 | 14000 | | pCi/Kg | 2000 |
| 301009 | GAMMA | LAL | Radium-223 | 380 | | pCi/Kg | |
| 301009 | GAMMA | LAL | Thallium-208 | 345 | | pCi/Kg | |
| 301009 | GAMMA | LAL | Thorium-234 | 1670 | | pCi/Kg | 550 |
| 301009 | GAMMA | LAL | Uranium-235 | 0 | | pCi/Kg | 190 |
| 301009 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301009 | ICP-MS | LAL | Beryllium | 0.46 | B | mg/Kg | |
| 301009 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301009 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301009 | ICP-MS | LAL | Thorium-232 | 4.5 | | mg/Kg | |
| 301009 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301009 | ICP-MS | LAL | Uranium-238 | 0.83 | | mg/Kg | |
| 301009 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 10.2 | | % | |
| 301010 | ALPHA | LAL | Thorium-228 | 1040 | | pCi/Kg | 150 |
| 301010 | ALPHA | LAL | Thorium-230 | 950 | | pCi/Kg | 130 |
| 301010 | ALPHA | LAL | Thorium-232 | 920 | | pCi/Kg | 130 |
| 301010 | ALPHA | LAL | Uranium-233/234 | 845 | | pCi/Kg | 85 |
| 301010 | ALPHA | LAL | Uranium-235 | 56 | | pCi/Kg | 21 |
| 301010 | ALPHA | LAL | Uranium-238 | 824 | | pCi/Kg | 83 |
| 301010 | BETA | LAL | Technetium-99 | 310 | | pCi/Kg | 200 |
| 301010 | GAMMA | LAL | Actinium-228 | 1070 | | pCi/Kg | |
| 301010 | GAMMA | LAL | Bismuth-212 | 580 | | pCi/Kg | |
| 301010 | GAMMA | LAL | Bismuth-214 | 1070 | | pCi/Kg | |
| 301010 | GAMMA | LAL | Cesium-137 | 54 | | pCi/Kg | 45 |
| 301010 | GAMMA | LAL | Cobalt 60 | -10 | | pCi/Kg | |
| 301010 | GAMMA | LAL | Lead-210 | 1260 | | pCi/Kg | |
| 301010 | GAMMA | LAL | Lead-212 | 1110 | | pCi/Kg | |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301010 | GAMMA | LAL | Lead-214 | 1250 | | pCi/Kg | |
| 301010 | GAMMA | LAL | Potassium-40 | 13700 | | pCi/Kg | 1800 |
| 301010 | GAMMA | LAL | Radium-223 | 230 | | pCi/Kg | |
| 301010 | GAMMA | LAL | Thallium-208 | 349 | | pCi/Kg | |
| 301010 | GAMMA | LAL | Thorium-234 | 1600 | | pCi/Kg | 470 |
| 301010 | GAMMA | LAL | Uranium-235 | 180 | | pCi/Kg | 170 |
| 301010 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301010 | ICP-MS | LAL | Beryllium | 0.36 | B | mg/Kg | |
| 301010 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301010 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301010 | ICP-MS | LAL | Thorium-232 | 4.3 | | mg/Kg | |
| 301010 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301010 | ICP-MS | LAL | Uranium-238 | 0.75 | | mg/Kg | |
| 301010 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 10.15 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location F04,02,29

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301005 | ALPHA | LAL | Neptunium-237 | 17 | | pCi/Kg | 16 |
| 301005 | ALPHA | LAL | Plutonium-238 | 0 | | pCi/Kg | 2.3 |
| 301005 | ALPHA | LAL | Plutonium-239/240 | 5.9 | | pCi/Kg | 5.4 |
| 301005 | ALPHA | LAL | Thorium-228 | 1140 | | pCi/Kg | 160 |
| 301005 | ALPHA | LAL | Thorium-230 | 970 | | pCi/Kg | 140 |
| 301005 | ALPHA | LAL | Thorium-232 | 860 | | pCi/Kg | 130 |
| 301005 | ALPHA | LAL | Uranium-233/234 | 808 | | pCi/Kg | 78 |
| 301005 | ALPHA | LAL | Uranium-235 | 43 | | pCi/Kg | 17 |
| 301005 | ALPHA | LAL | Uranium-238 | 820 | | pCi/Kg | 79 |
| 301005 | BETA | LAL | Strontium-90 | 60 | | pCi/Kg | |
| 301005 | BETA | LAL | Technetium-99 | 160 | | pCi/Kg | 190 |
| 301005 | GAMMA | LAL | Actinium-228 | 1130 | | pCi/Kg | |
| 301005 | GAMMA | LAL | Bismuth-212 | 580 | | pCi/Kg | |
| 301005 | GAMMA | LAL | Bismuth-214 | 990 | | pCi/Kg | |
| 301005 | GAMMA | LAL | Cesium-137 | 199 | | pCi/Kg | 37 |
| 301005 | GAMMA | LAL | Cobalt 60 | -10 | | pCi/Kg | |
| 301005 | GAMMA | LAL | Lead-210 | 2800 | | pCi/Kg | |
| 301005 | GAMMA | LAL | Lead-212 | 980 | | pCi/Kg | |
| 301005 | GAMMA | LAL | Lead-214 | 1180 | | pCi/Kg | |
| 301005 | GAMMA | LAL | Potassium-40 | 13700 | | pCi/Kg | 1600 |
| 301005 | GAMMA | LAL | Radium-223 | -20 | | pCi/Kg | |
| 301005 | GAMMA | LAL | Thallium-208 | 336 | | pCi/Kg | |
| 301005 | GAMMA | LAL | Thorium-234 | 980 | | pCi/Kg | 430 |
| 301005 | GAMMA | LAL | Uranium-235 | 20 | | pCi/Kg | 130 |
| 301005 | ICP-MS | LAL | Antimony | 0.18 | UN | mg/Kg | |
| 301005 | ICP-MS | LAL | Beryllium | 0.39 | B | mg/Kg | |
| 301005 | ICP-MS | LAL | Cadmium | 0.18 | U | mg/Kg | |
| 301005 | ICP-MS | LAL | Thallium | 0.18 | U | mg/Kg | |
| 301005 | ICP-MS | LAL | Thorium-232 | 4.1 | | mg/Kg | |
| 301005 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301005 | ICP-MS | LAL | Uranium-238 | 0.81 | | mg/Kg | |
| 301005 | NAA | ORN | Thorium-232 | 8.2 | | mg/Kg | |
| 301005 | NAA | ORN | Uranium-235 | 0.02 | | mg/Kg | |
| 301005 | NAA | ORN | Uranium-238 | 2.8 | | mg/Kg | |
| 301005 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 9.64 | | % | |
| 301006 | ALPHA | LAL | Thorium-228 | 1130 | | pCi/Kg | 160 |
| 301006 | ALPHA | LAL | Thorium-230 | 1010 | | pCi/Kg | 140 |
| 301006 | ALPHA | LAL | Thorium-232 | 1070 | | pCi/Kg | 140 |
| 301006 | ALPHA | LAL | Uranium-233/234 | 794 | | pCi/Kg | 77 |
| 301006 | ALPHA | LAL | Uranium-235 | 44 | | pCi/Kg | 16 |
| 301006 | ALPHA | LAL | Uranium-238 | 820 | | pCi/Kg | 78 |
| 301006 | BETA | LAL | Technetium-99 | 330 | | pCi/Kg | 230 |
| 301006 | GAMMA | LAL | Actinium-228 | 960 | | pCi/Kg | |
| 301006 | GAMMA | LAL | Bismuth-212 | 680 | | pCi/Kg | |
| 301006 | GAMMA | LAL | Bismuth-214 | 1050 | | pCi/Kg | |
| 301006 | GAMMA | LAL | Cesium-137 | 25 | | pCi/Kg | 36 |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301006 | GAMMA | LAL | Cobalt 60 | -8 | | pCi/Kg | |
| 301006 | GAMMA | LAL | Lead-210 | 1850 | | pCi/Kg | |
| 301006 | GAMMA | LAL | Lead-212 | 1110 | | pCi/Kg | |
| 301006 | GAMMA | LAL | Lead-214 | 1230 | | pCi/Kg | |
| 301006 | GAMMA | LAL | Potassium-40 | 13800 | | pCi/Kg | 1800 |
| 301006 | GAMMA | LAL | Radium-223 | 220 | | pCi/Kg | |
| 301006 | GAMMA | LAL | Thallium-208 | 338 | | pCi/Kg | |
| 301006 | GAMMA | LAL | Thorium-234 | 1380 | | pCi/Kg | 430 |
| 301006 | GAMMA | LAL | Uranium-235 | 160 | | pCi/Kg | 160 |
| 301006 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301006 | ICP-MS | LAL | Beryllium | 0.46 | B | mg/Kg | |
| 301006 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301006 | ICP-MS | LAL | Thallium | 0.24 | B | mg/Kg | |
| 301006 | ICP-MS | LAL | Thorium-232 | 4.1 | | mg/Kg | |
| 301006 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301006 | ICP-MS | LAL | Uranium-238 | 0.77 | | mg/Kg | |
| 301006 | NAA | ORN | Thorium-232 | 8.8 | | mg/Kg | |
| 301006 | NAA | ORN | Uranium-235 | 0.02 | | mg/Kg | |
| 301006 | NAA | ORN | Uranium-238 | 2.9 | | mg/Kg | |
| 301006 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 10.79 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location F05,07,17

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301007 | ALPHA | LAL | Neptunium-237 | 17 | | pCi/Kg | 16 |
| 301007 | ALPHA | LAL | Plutonium-238 | 0.8 | | pCi/Kg | 3.6 |
| 301007 | ALPHA | LAL | Plutonium-239/240 | 8.1 | | pCi/Kg | 6 |
| 301007 | ALPHA | LAL | Thorium-228 | 950 | | pCi/Kg | 130 |
| 301007 | ALPHA | LAL | Thorium-230 | 920 | | pCi/Kg | 120 |
| 301007 | ALPHA | LAL | Thorium-232 | 940 | | pCi/Kg | 120 |
| 301007 | ALPHA | LAL | Uranium-233/234 | 845 | | pCi/Kg | 78 |
| 301007 | ALPHA | LAL | Uranium-235 | 33 | | pCi/Kg | 14 |
| 301007 | ALPHA | LAL | Uranium-238 | 925 | | pCi/Kg | 83 |
| 301007 | BETA | LAL | Strontium-90 | -170 | | pCi/Kg | |
| 301007 | BETA | LAL | Technetium-99 | 320 | | pCi/Kg | 210 |
| 301007 | GAMMA | LAL | Actinium-228 | 1090 | | pCi/Kg | |
| 301007 | GAMMA | LAL | Bismuth-212 | 490 | | pCi/Kg | |
| 301007 | GAMMA | LAL | Bismuth-214 | 1050 | | pCi/Kg | |
| 301007 | GAMMA | LAL | Cesium-137 | 262 | | pCi/Kg | 44 |
| 301007 | GAMMA | LAL | Cobalt 60 | -6 | | pCi/Kg | |
| 301007 | GAMMA | LAL | Lead-210 | -1100 | | pCi/Kg | |
| 301007 | GAMMA | LAL | Lead-212 | 950 | | pCi/Kg | |
| 301007 | GAMMA | LAL | Lead-214 | 1210 | | pCi/Kg | |
| 301007 | GAMMA | LAL | Potassium-40 | 13600 | | pCi/Kg | 1600 |
| 301007 | GAMMA | LAL | Radium-223 | -40 | | pCi/Kg | |
| 301007 | GAMMA | LAL | Thallium-208 | 352 | | pCi/Kg | |
| 301007 | GAMMA | LAL | Thorium-234 | 1250 | | pCi/Kg | 460 |
| 301007 | GAMMA | LAL | Uranium-235 | 30 | | pCi/Kg | 130 |
| 301007 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301007 | ICP-MS | LAL | Beryllium | 0.46 | B | mg/Kg | |
| 301007 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301007 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301007 | ICP-MS | LAL | Thorium-232 | 4.1 | | mg/Kg | |
| 301007 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301007 | ICP-MS | LAL | Uranium-238 | 0.93 | | mg/Kg | |
| 301007 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 11.05 | | % | |
| 301008 | ALPHA | LAL | Thorium-228 | 1160 | | pCi/Kg | 160 |
| 301008 | ALPHA | LAL | Thorium-230 | 1060 | | pCi/Kg | 140 |
| 301008 | ALPHA | LAL | Thorium-232 | 1030 | | pCi/Kg | 140 |
| 301008 | ALPHA | LAL | Uranium-233/234 | 855 | | pCi/Kg | 86 |
| 301008 | ALPHA | LAL | Uranium-235 | 76 | | pCi/Kg | 23 |
| 301008 | ALPHA | LAL | Uranium-238 | 863 | | pCi/Kg | 86 |
| 301008 | BETA | LAL | Technetium-99 | 240 | | pCi/Kg | 190 |
| 301008 | GAMMA | LAL | Actinium-228 | 1030 | | pCi/Kg | |
| 301008 | GAMMA | LAL | Bismuth-212 | 470 | | pCi/Kg | |
| 301008 | GAMMA | LAL | Bismuth-214 | 960 | | pCi/Kg | |
| 301008 | GAMMA | LAL | Cesium-137 | 152 | | pCi/Kg | 32 |
| 301008 | GAMMA | LAL | Cobalt 60 | -1 | | pCi/Kg | |
| 301008 | GAMMA | LAL | Lead-210 | 2200 | | pCi/Kg | |
| 301008 | GAMMA | LAL | Lead-212 | 940 | | pCi/Kg | |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301008 | GAMMA | LAL | Lead-214 | 1150 | | pCi/Kg | |
| 301008 | GAMMA | LAL | Potassium-40 | 13500 | | pCi/Kg | 1600 |
| 301008 | GAMMA | LAL | Radium-223 | 0 | | pCi/Kg | |
| 301008 | GAMMA | LAL | Thallium-208 | 328 | | pCi/Kg | |
| 301008 | GAMMA | LAL | Thorium-234 | 890 | | pCi/Kg | 440 |
| 301008 | GAMMA | LAL | Uranium-235 | -70 | | pCi/Kg | 120 |
| 301008 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301008 | ICP-MS | LAL | Beryllium | 0.44 | B | mg/Kg | |
| 301008 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301008 | ICP-MS | LAL | Thallium | 0.21 | B | mg/Kg | |
| 301008 | ICP-MS | LAL | Thorium-232 | 4 | | mg/Kg | |
| 301008 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301008 | ICP-MS | LAL | Uranium-238 | 0.81 | | mg/Kg | |
| 301008 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 11.04 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location F12,20,22

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301001 | ALPHA | LAL | Neptunium-237 | 14 | | pCi/Kg | 19 |
| 301001 | ALPHA | LAL | Plutonium-238 | 4.9 | | pCi/Kg | 5.1 |
| 301001 | ALPHA | LAL | Plutonium-239/240 | 10.7 | | pCi/Kg | 6.2 |
| 301001 | ALPHA | LAL | Thorium-228 | 970 | | pCi/Kg | 140 |
| 301001 | ALPHA | LAL | Thorium-230 | 990 | | pCi/Kg | 130 |
| 301001 | ALPHA | LAL | Thorium-232 | 960 | | pCi/Kg | 130 |
| 301001 | ALPHA | LAL | Uranium-233/234 | 874 | | pCi/Kg | 80 |
| 301001 | ALPHA | LAL | Uranium-235 | 44 | | pCi/Kg | 16 |
| 301001 | ALPHA | LAL | Uranium-238 | 902 | | pCi/Kg | 82 |
| 301001 | BETA | LAL | Strontium-90 | 90 | | pCi/Kg | |
| 301001 | BETA | LAL | Technetium-99 | 100 | | pCi/Kg | 180 |
| 301001 | GAMMA | LAL | Actinium-228 | 940 | | pCi/Kg | |
| 301001 | GAMMA | LAL | Bismuth-212 | 560 | | pCi/Kg | |
| 301001 | GAMMA | LAL | Bismuth-214 | 930 | | pCi/Kg | |
| 301001 | GAMMA | LAL | Cesium-137 | 240 | | pCi/Kg | 39 |
| 301001 | GAMMA | LAL | Cobalt 60 | -11 | | pCi/Kg | |
| 301001 | GAMMA | LAL | Lead-210 | 1900 | | pCi/Kg | |
| 301001 | GAMMA | LAL | Lead-212 | 950 | | pCi/Kg | |
| 301001 | GAMMA | LAL | Lead-214 | 1041 | | pCi/Kg | |
| 301001 | GAMMA | LAL | Potassium-40 | 13800 | | pCi/Kg | 1600 |
| 301001 | GAMMA | LAL | Radium-223 | -30 | | pCi/Kg | |
| 301001 | GAMMA | LAL | Thallium-208 | 286 | | pCi/Kg | |
| 301001 | GAMMA | LAL | Thorium-234 | 1260 | | pCi/Kg | 420 |
| 301001 | GAMMA | LAL | Uranium-235 | 110 | | pCi/Kg | 120 |
| 301001 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301001 | ICP-MS | LAL | Beryllium | 0.48 | B | mg/Kg | |
| 301001 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301001 | ICP-MS | LAL | Thallium | 0.2 | B | mg/Kg | |
| 301001 | ICP-MS | LAL | Thorium-232 | 4.6 | | mg/Kg | |
| 301001 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301001 | ICP-MS | LAL | Uranium-238 | 0.91 | | mg/Kg | |
| 301001 | NAA | ORN | Thorium-232 | 8.5 | | mg/Kg | |
| 301001 | NAA | ORN | Uranium-235 | 0.022 | | mg/Kg | |
| 301001 | NAA | ORN | Uranium-238 | 2.8 | | mg/Kg | |
| 301001 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 13.78 | | % | |
| 301002 | ALPHA | LAL | Neptunium-237 | 18 | | pCi/Kg | 18 |
| 301002 | ALPHA | LAL | Plutonium-238 | 1.6 | | pCi/Kg | 3.9 |
| 301002 | ALPHA | LAL | Plutonium-239/240 | 8.1 | | pCi/Kg | 5 |
| 301002 | ALPHA | LAL | Thorium-228 | 1050 | | pCi/Kg | 150 |
| 301002 | ALPHA | LAL | Thorium-230 | 1060 | | pCi/Kg | 130 |
| 301002 | ALPHA | LAL | Thorium-232 | 1080 | | pCi/Kg | 140 |
| 301002 | ALPHA | LAL | Uranium-233/234 | 941 | | pCi/Kg | 87 |
| 301002 | ALPHA | LAL | Uranium-235 | 47 | | pCi/Kg | 17 |
| 301002 | ALPHA | LAL | Uranium-238 | 931 | | pCi/Kg | 86 |
| 301002 | BETA | LAL | Strontium-90 | 220 | | pCi/Kg | |
| 301002 | BETA | LAL | Technetium-99 | -110 | | pCi/Kg | 180 |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301002 | GAMMA | LAL | Actinium-228 | 1060 | | pCi/Kg | |
| 301002 | GAMMA | LAL | Bismuth-212 | 420 | | pCi/Kg | |
| 301002 | GAMMA | LAL | Bismuth-214 | 930 | | pCi/Kg | |
| 301002 | GAMMA | LAL | Cesium-137 | 250 | | pCi/Kg | 41 |
| 301002 | GAMMA | LAL | Cobalt 60 | 10 | | pCi/Kg | |
| 301002 | GAMMA | LAL | Lead-210 | 1400 | | pCi/Kg | |
| 301002 | GAMMA | LAL | Lead-212 | 960 | | pCi/Kg | |
| 301002 | GAMMA | LAL | Lead-214 | 1160 | | pCi/Kg | |
| 301002 | GAMMA | LAL | Potassium-40 | 13500 | | pCi/Kg | 1600 |
| 301002 | GAMMA | LAL | Radium-223 | -110 | | pCi/Kg | |
| 301002 | GAMMA | LAL | Thallium-208 | 330 | | pCi/Kg | |
| 301002 | GAMMA | LAL | Thorium-234 | 1290 | | pCi/Kg | 440 |
| 301002 | GAMMA | LAL | Uranium-235 | 0 | | pCi/Kg | 130 |
| 301002 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301002 | ICP-MS | LAL | Beryllium | 0.46 | B | mg/Kg | |
| 301002 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301002 | ICP-MS | LAL | Thallium | 0.2 | B | mg/Kg | |
| 301002 | ICP-MS | LAL | Thorium-232 | 4.8 | | mg/Kg | |
| 301002 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301002 | ICP-MS | LAL | Uranium-238 | 0.96 | | mg/Kg | |
| 301002 | NAA | ORN | Thorium-232 | 8.6 | | mg/Kg | |
| 301002 | NAA | ORN | Uranium-235 | 0.021 | | mg/Kg | |
| 301002 | NAA | ORN | Uranium-238 | 3.2 | | mg/Kg | |
| 301002 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 14.31 | | % | |
| 301003 | ALPHA | LAL | Thorium-228 | 1080 | | pCi/Kg | 140 |
| 301003 | ALPHA | LAL | Thorium-230 | 880 | | pCi/Kg | 120 |
| 301003 | ALPHA | LAL | Thorium-232 | 870 | | pCi/Kg | 120 |
| 301003 | ALPHA | LAL | Uranium-233/234 | 826 | | pCi/Kg | 79 |
| 301003 | ALPHA | LAL | Uranium-235 | 42 | | pCi/Kg | 15 |
| 301003 | ALPHA | LAL | Uranium-238 | 923 | | pCi/Kg | 85 |
| 301003 | BETA | LAL | Technetium-99 | 20 | | pCi/Kg | 190 |
| 301003 | GAMMA | LAL | Actinium-228 | 1020 | | pCi/Kg | |
| 301003 | GAMMA | LAL | Bismuth-212 | 620 | | pCi/Kg | |
| 301003 | GAMMA | LAL | Bismuth-214 | 950 | | pCi/Kg | |
| 301003 | GAMMA | LAL | Cesium-137 | 104 | | pCi/Kg | 26 |
| 301003 | GAMMA | LAL | Cobalt 60 | -15.2 | | pCi/Kg | |
| 301003 | GAMMA | LAL | Lead-210 | 1500 | | pCi/Kg | |
| 301003 | GAMMA | LAL | Lead-212 | 960 | | pCi/Kg | |
| 301003 | GAMMA | LAL | Lead-214 | 1130 | | pCi/Kg | |
| 301003 | GAMMA | LAL | Potassium-40 | 13500 | | pCi/Kg | 1500 |
| 301003 | GAMMA | LAL | Radium-223 | -120 | | pCi/Kg | |
| 301003 | GAMMA | LAL | Thallium-208 | 316 | | pCi/Kg | |
| 301003 | GAMMA | LAL | Thorium-234 | 1000 | | pCi/Kg | 390 |
| 301003 | GAMMA | LAL | Uranium-235 | 80 | | pCi/Kg | 120 |
| 301003 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301003 | ICP-MS | LAL | Beryllium | 0.48 | B | mg/Kg | |
| 301003 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301003 | ICP-MS | LAL | Thallium | 0.24 | B | mg/Kg | |
| 301003 | ICP-MS | LAL | Thorium-232 | 5 | | mg/Kg | |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301003 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301003 | ICP-MS | LAL | Uranium-238 | 0.93 | | mg/Kg | |
| 301003 | NAA | ORN | Thorium-232 | 8.6 | | mg/Kg | |
| 301003 | NAA | ORN | Uranium-235 | 0.022 | | mg/Kg | |
| 301003 | NAA | ORN | Uranium-238 | 2.8 | | mg/Kg | |
| 301003 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 14.29 | | % | |
| 301004 | ALPHA | LAL | Thorium-228 | 1200 | | pCi/Kg | 150 |
| 301004 | ALPHA | LAL | Thorium-230 | 990 | | pCi/Kg | 130 |
| 301004 | ALPHA | LAL | Thorium-232 | 1010 | | pCi/Kg | 130 |
| 301004 | ALPHA | LAL | Uranium-233/234 | 779 | | pCi/Kg | 75 |
| 301004 | ALPHA | LAL | Uranium-235 | 38 | | pCi/Kg | 15 |
| 301004 | ALPHA | LAL | Uranium-238 | 895 | | pCi/Kg | 82 |
| 301004 | BETA | LAL | Technetium-99 | 350 | | pCi/Kg | 210 |
| 301004 | GAMMA | LAL | Actinium-228 | 1020 | | pCi/Kg | |
| 301004 | GAMMA | LAL | Bismuth-212 | 580 | | pCi/Kg | |
| 301004 | GAMMA | LAL | Bismuth-214 | 990 | | pCi/Kg | |
| 301004 | GAMMA | LAL | Cesium-137 | 149 | | pCi/Kg | 41 |
| 301004 | GAMMA | LAL | Cobalt 60 | -28 | | pCi/Kg | |
| 301004 | GAMMA | LAL | Lead-210 | 2460 | | pCi/Kg | |
| 301004 | GAMMA | LAL | Lead-212 | 1130 | | pCi/Kg | |
| 301004 | GAMMA | LAL | Lead-214 | 1250 | | pCi/Kg | |
| 301004 | GAMMA | LAL | Potassium-40 | 13600 | | pCi/Kg | 1800 |
| 301004 | GAMMA | LAL | Radium-223 | 20 | | pCi/Kg | |
| 301004 | GAMMA | LAL | Thallium-208 | 319 | | pCi/Kg | |
| 301004 | GAMMA | LAL | Thorium-234 | 1510 | | pCi/Kg | 410 |
| 301004 | GAMMA | LAL | Uranium-235 | 170 | | pCi/Kg | 150 |
| 301004 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301004 | ICP-MS | LAL | Beryllium | 0.45 | B | mg/Kg | |
| 301004 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301004 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301004 | ICP-MS | LAL | Thorium-232 | 5 | | mg/Kg | |
| 301004 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301004 | ICP-MS | LAL | Uranium-238 | 0.89 | | mg/Kg | |
| 301004 | NAA | ORN | Thorium-232 | 8.8 | | mg/Kg | |
| 301004 | NAA | ORN | Uranium-235 | 0.021 | | mg/Kg | |
| 301004 | NAA | ORN | Uranium-238 | 3.7 | | mg/Kg | |
| 301004 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 13.98 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location H01,05,15

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301025 | ALPHA | LAL | Neptunium-237 | -3 | | pCi/Kg | 12 |
| 301025 | ALPHA | LAL | Plutonium-238 | 4 | | pCi/Kg | 3.5 |
| 301025 | ALPHA | LAL | Plutonium-239/240 | 11.2 | | pCi/Kg | 7 |
| 301025 | ALPHA | LAL | Thorium-228 | 1120 | | pCi/Kg | 170 |
| 301025 | ALPHA | LAL | Thorium-230 | 1130 | | pCi/Kg | 160 |
| 301025 | ALPHA | LAL | Thorium-232 | 1000 | | pCi/Kg | 150 |
| 301025 | ALPHA | LAL | Uranium-233/234 | 1023 | | pCi/Kg | 100 |
| 301025 | ALPHA | LAL | Uranium-235 | 44 | | pCi/Kg | 18 |
| 301025 | ALPHA | LAL | Uranium-238 | 956 | | pCi/Kg | 97 |
| 301025 | BETA | LAL | Strontium-90 | -80 | | pCi/Kg | |
| 301025 | BETA | LAL | Technetium-99 | -70 | | pCi/Kg | 170 |
| 301025 | GAMMA | LAL | Actinium-228 | 1240 | | pCi/Kg | |
| 301025 | GAMMA | LAL | Bismuth-212 | 550 | | pCi/Kg | |
| 301025 | GAMMA | LAL | Bismuth-214 | 1270 | | pCi/Kg | |
| 301025 | GAMMA | LAL | Cesium-137 | 378 | | pCi/Kg | 82 |
| 301025 | GAMMA | LAL | Cobalt 60 | -16 | | pCi/Kg | |
| 301025 | GAMMA | LAL | Lead-210 | 3700 | | pCi/Kg | |
| 301025 | GAMMA | LAL | Lead-212 | 1140 | | pCi/Kg | |
| 301025 | GAMMA | LAL | Lead-214 | 1260 | | pCi/Kg | |
| 301025 | GAMMA | LAL | Potassium-40 | 11800 | | pCi/Kg | 1700 |
| 301025 | GAMMA | LAL | Radium-223 | -200 | | pCi/Kg | |
| 301025 | GAMMA | LAL | Thallium-208 | 337 | | pCi/Kg | |
| 301025 | GAMMA | LAL | Thorium-234 | 1780 | | pCi/Kg | 530 |
| 301025 | GAMMA | LAL | Uranium-235 | 80 | | pCi/Kg | 180 |
| 301025 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301025 | ICP-MS | LAL | Beryllium | 0.39 | B | mg/Kg | |
| 301025 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301025 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301025 | ICP-MS | LAL | Thorium-232 | 4.6 | | mg/Kg | |
| 301025 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301025 | ICP-MS | LAL | Uranium-238 | 0.99 | | mg/Kg | |
| 301025 | NAA | ORN | Thorium-232 | 8.7 | | mg/Kg | |
| 301025 | NAA | ORN | Uranium-235 | 0.022 | | mg/Kg | |
| 301025 | NAA | ORN | Uranium-238 | 3 | | mg/Kg | |
| 301025 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 10.81 | | % | |
| 301026 | ALPHA | LAL | Thorium-228 | 890 | | pCi/Kg | 130 |
| 301026 | ALPHA | LAL | Thorium-230 | 1040 | | pCi/Kg | 130 |
| 301026 | ALPHA | LAL | Thorium-232 | 930 | | pCi/Kg | 120 |
| 301026 | ALPHA | LAL | Uranium-233/234 | 903 | | pCi/Kg | 82 |
| 301026 | ALPHA | LAL | Uranium-235 | 44 | | pCi/Kg | 16 |
| 301026 | ALPHA | LAL | Uranium-238 | 869 | | pCi/Kg | 80 |
| 301026 | BETA | LAL | Technetium-99 | 30 | | pCi/Kg | 190 |
| 301026 | GAMMA | LAL | Actinium-228 | 1390 | | pCi/Kg | |
| 301026 | GAMMA | LAL | Bismuth-212 | 560 | | pCi/Kg | |
| 301026 | GAMMA | LAL | Bismuth-214 | 1320 | | pCi/Kg | |
| 301026 | GAMMA | LAL | Cesium-137 | 5 | | pCi/Kg | 32 |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301026 | GAMMA | LAL | Cobalt 60 | -9 | | pCi/Kg | |
| 301026 | GAMMA | LAL | Lead-210 | 1570 | | pCi/Kg | |
| 301026 | GAMMA | LAL | Lead-212 | 1420 | | pCi/Kg | |
| 301026 | GAMMA | LAL | Lead-214 | 1500 | | pCi/Kg | |
| 301026 | GAMMA | LAL | Potassium-40 | 13200 | | pCi/Kg | 1800 |
| 301026 | GAMMA | LAL | Radium-223 | -160 | | pCi/Kg | |
| 301026 | GAMMA | LAL | Thallium-208 | 454 | | pCi/Kg | |
| 301026 | GAMMA | LAL | Thorium-234 | 1680 | | pCi/Kg | 470 |
| 301026 | GAMMA | LAL | Uranium-235 | 140 | | pCi/Kg | 170 |
| 301026 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301026 | ICP-MS | LAL | Beryllium | 0.42 | B | mg/Kg | |
| 301026 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301026 | ICP-MS | LAL | Thallium | 0.21 | B | mg/Kg | |
| 301026 | ICP-MS | LAL | Thorium-232 | 6.6 | | mg/Kg | |
| 301026 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301026 | ICP-MS | LAL | Uranium-238 | 1.1 | | mg/Kg | |
| 301026 | NAA | ORN | Thorium-232 | 9.3 | | mg/Kg | |
| 301026 | NAA | ORN | Uranium-235 | 0.022 | | mg/Kg | |
| 301026 | NAA | ORN | Uranium-238 | 3 | | mg/Kg | |
| 301026 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 20.82 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location H02,10,18

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301027 | ALPHA | LAL | Neptunium-237 | 19 | | pCi/Kg | 18 |
| 301027 | ALPHA | LAL | Plutonium-238 | 1.5 | | pCi/Kg | 2.9 |
| 301027 | ALPHA | LAL | Plutonium-239/240 | 5.9 | | pCi/Kg | 5.4 |
| 301027 | ALPHA | LAL | Thorium-228 | 1110 | | pCi/Kg | 170 |
| 301027 | ALPHA | LAL | Thorium-230 | 1180 | | pCi/Kg | 160 |
| 301027 | ALPHA | LAL | Thorium-232 | 1200 | | pCi/Kg | 160 |
| 301027 | ALPHA | LAL | Uranium-233/234 | 1010 | | pCi/Kg | 110 |
| 301027 | ALPHA | LAL | Uranium-235 | 78 | | pCi/Kg | 26 |
| 301027 | ALPHA | LAL | Uranium-238 | 1000 | | pCi/Kg | 110 |
| 301027 | BETA | LAL | Strontium-90 | -50 | | pCi/Kg | |
| 301027 | BETA | LAL | Technetium-99 | 70 | | pCi/Kg | 170 |
| 301027 | GAMMA | LAL | Actinium-228 | 1110 | | pCi/Kg | |
| 301027 | GAMMA | LAL | Bismuth-212 | 440 | | pCi/Kg | |
| 301027 | GAMMA | LAL | Bismuth-214 | 1130 | | pCi/Kg | |
| 301027 | GAMMA | LAL | Cesium-137 | 231 | | pCi/Kg | 61 |
| 301027 | GAMMA | LAL | Cobalt 60 | -18 | | pCi/Kg | |
| 301027 | GAMMA | LAL | Lead-210 | 1440 | | pCi/Kg | |
| 301027 | GAMMA | LAL | Lead-212 | 1180 | | pCi/Kg | |
| 301027 | GAMMA | LAL | Lead-214 | 1530 | | pCi/Kg | |
| 301027 | GAMMA | LAL | Potassium-40 | 13000 | | pCi/Kg | 1800 |
| 301027 | GAMMA | LAL | Radium-223 | -180 | | pCi/Kg | |
| 301027 | GAMMA | LAL | Thallium-208 | 387 | | pCi/Kg | |
| 301027 | GAMMA | LAL | Thorium-234 | 1380 | | pCi/Kg | 480 |
| 301027 | GAMMA | LAL | Uranium-235 | 140 | | pCi/Kg | 180 |
| 301027 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301027 | ICP-MS | LAL | Beryllium | 0.4 | B | mg/Kg | |
| 301027 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301027 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301027 | ICP-MS | LAL | Thorium-232 | 4.9 | | mg/Kg | |
| 301027 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301027 | ICP-MS | LAL | Uranium-238 | 0.94 | | mg/Kg | |
| 301027 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 17.13 | | % | |
| 301028 | ALPHA | LAL | Thorium-228 | 1190 | | pCi/Kg | 150 |
| 301028 | ALPHA | LAL | Thorium-230 | 1070 | | pCi/Kg | 130 |
| 301028 | ALPHA | LAL | Thorium-232 | 1140 | | pCi/Kg | 140 |
| 301028 | ALPHA | LAL | Uranium-233/234 | 884 | | pCi/Kg | 80 |
| 301028 | ALPHA | LAL | Uranium-235 | 48 | | pCi/Kg | 16 |
| 301028 | ALPHA | LAL | Uranium-238 | 919 | | pCi/Kg | 82 |
| 301028 | BETA | LAL | Technetium-99 | 3050 | | pCi/Kg | 370 |
| 301028 | GAMMA | LAL | Actinium-228 | 1260 | | pCi/Kg | |
| 301028 | GAMMA | LAL | Bismuth-212 | 730 | | pCi/Kg | |
| 301028 | GAMMA | LAL | Bismuth-214 | 1150 | | pCi/Kg | |
| 301028 | GAMMA | LAL | Cesium-137 | 138 | | pCi/Kg | 54 |
| 301028 | GAMMA | LAL | Cobalt 60 | 2 | | pCi/Kg | |
| 301028 | GAMMA | LAL | Lead-210 | 1070 | | pCi/Kg | |
| 301028 | GAMMA | LAL | Lead-212 | 1220 | | pCi/Kg | |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301028 | GAMMA | LAL | Lead-214 | 1460 | | pCi/Kg | |
| 301028 | GAMMA | LAL | Potassium-40 | 12600 | | pCi/Kg | 1700 |
| 301028 | GAMMA | LAL | Radium-223 | 180 | | pCi/Kg | |
| 301028 | GAMMA | LAL | Thallium-208 | 404 | | pCi/Kg | |
| 301028 | GAMMA | LAL | Thorium-234 | 1810 | | pCi/Kg | 490 |
| 301028 | GAMMA | LAL | Uranium-235 | 70 | | pCi/Kg | 170 |
| 301028 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301028 | ICP-MS | LAL | Beryllium | 0.5 | B | mg/Kg | |
| 301028 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301028 | ICP-MS | LAL | Thallium | 0.23 | B | mg/Kg | |
| 301028 | ICP-MS | LAL | Thorium-232 | 6 | | mg/Kg | |
| 301028 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301028 | ICP-MS | LAL | Uranium-238 | 0.97 | | mg/Kg | |
| 301028 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 20.2 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location H03,07,13

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301029 | ALPHA | LAL | Neptunium-237 | 10 | | pCi/Kg | 16 |
| 301029 | ALPHA | LAL | Plutonium-238 | 2.2 | | pCi/Kg | 3.8 |
| 301029 | ALPHA | LAL | Plutonium-239/240 | 16.3 | | pCi/Kg | 6.8 |
| 301029 | ALPHA | LAL | Thorium-228 | 1070 | | pCi/Kg | 160 |
| 301029 | ALPHA | LAL | Thorium-230 | 1090 | | pCi/Kg | 150 |
| 301029 | ALPHA | LAL | Thorium-232 | 990 | | pCi/Kg | 140 |
| 301029 | ALPHA | LAL | Uranium-233/234 | 930 | | pCi/Kg | 110 |
| 301029 | ALPHA | LAL | Uranium-235 | 77 | | pCi/Kg | 28 |
| 301029 | ALPHA | LAL | Uranium-238 | 1100 | | pCi/Kg | 120 |
| 301029 | BETA | LAL | Strontium-90 | 120 | | pCi/Kg | |
| 301029 | BETA | LAL | Technetium-99 | 470 | | pCi/Kg | 200 |
| 301029 | GAMMA | LAL | Actinium-228 | 1170 | | pCi/Kg | |
| 301029 | GAMMA | LAL | Bismuth-212 | 600 | | pCi/Kg | |
| 301029 | GAMMA | LAL | Bismuth-214 | 1020 | | pCi/Kg | |
| 301029 | GAMMA | LAL | Cesium-137 | 384 | | pCi/Kg | 57 |
| 301029 | GAMMA | LAL | Cobalt 60 | 10 | | pCi/Kg | |
| 301029 | GAMMA | LAL | Lead-210 | 1100 | | pCi/Kg | |
| 301029 | GAMMA | LAL | Lead-212 | 1170 | | pCi/Kg | |
| 301029 | GAMMA | LAL | Lead-214 | 1340 | | pCi/Kg | |
| 301029 | GAMMA | LAL | Potassium-40 | 13500 | | pCi/Kg | 1600 |
| 301029 | GAMMA | LAL | Radium-223 | -80 | | pCi/Kg | |
| 301029 | GAMMA | LAL | Thallium-208 | 354 | | pCi/Kg | |
| 301029 | GAMMA | LAL | Thorium-234 | 1400 | | pCi/Kg | 510 |
| 301029 | GAMMA | LAL | Uranium-235 | 70 | | pCi/Kg | 150 |
| 301029 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301029 | ICP-MS | LAL | Beryllium | 0.44 | B | mg/Kg | |
| 301029 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301029 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301029 | ICP-MS | LAL | Thorium-232 | 5.2 | | mg/Kg | |
| 301029 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301029 | ICP-MS | LAL | Uranium-238 | 1.1 | | mg/Kg | |
| 301029 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 11.44 | | % | |
| 301030 | ALPHA | LAL | Thorium-228 | 1250 | | pCi/Kg | 150 |
| 301030 | ALPHA | LAL | Thorium-230 | 1250 | | pCi/Kg | 140 |
| 301030 | ALPHA | LAL | Thorium-232 | 1190 | | pCi/Kg | 140 |
| 301030 | ALPHA | LAL | Uranium-233/234 | 872 | | pCi/Kg | 81 |
| 301030 | ALPHA | LAL | Uranium-235 | 42 | | pCi/Kg | 15 |
| 301030 | ALPHA | LAL | Uranium-238 | 825 | | pCi/Kg | 78 |
| 301030 | BETA | LAL | Technetium-99 | 30 | | pCi/Kg | 190 |
| 301030 | GAMMA | LAL | Actinium-228 | 1320 | | pCi/Kg | |
| 301030 | GAMMA | LAL | Bismuth-212 | 760 | | pCi/Kg | |
| 301030 | GAMMA | LAL | Bismuth-214 | 1100 | | pCi/Kg | |
| 301030 | GAMMA | LAL | Cesium-137 | -29 | | pCi/Kg | 22 |
| 301030 | GAMMA | LAL | Cobalt 60 | -12 | | pCi/Kg | |
| 301030 | GAMMA | LAL | Lead-210 | 800 | | pCi/Kg | |
| 301030 | GAMMA | LAL | Lead-212 | 1210 | | pCi/Kg | |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301030 | GAMMA | LAL | Lead-214 | 1380 | | pCi/Kg | |
| 301030 | GAMMA | LAL | Potassium-40 | 13200 | | pCi/Kg | 1600 |
| 301030 | GAMMA | LAL | Radium-223 | -130 | | pCi/Kg | |
| 301030 | GAMMA | LAL | Thallium-208 | 355 | | pCi/Kg | |
| 301030 | GAMMA | LAL | Thorium-234 | 1090 | | pCi/Kg | 480 |
| 301030 | GAMMA | LAL | Uranium-235 | 100 | | pCi/Kg | 140 |
| 301030 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301030 | ICP-MS | LAL | Beryllium | 0.57 | B | mg/Kg | |
| 301030 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301030 | ICP-MS | LAL | Thallium | 0.23 | B | mg/Kg | |
| 301030 | ICP-MS | LAL | Thorium-232 | 6.7 | | mg/Kg | |
| 301030 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301030 | ICP-MS | LAL | Uranium-238 | 1.2 | | mg/Kg | |
| 301030 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 18.95 | | % | |

# Background Soils Project Analytical Data

3/10/97

## Location H04,06,09

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 301021 | ALPHA | LAL | Neptunium-237 | 29 | | pCi/Kg | 22 |
| 301021 | ALPHA | LAL | Plutonium-238 | 0 | | pCi/Kg | 0 |
| 301021 | ALPHA | LAL | Plutonium-239/240 | 11.3 | | pCi/Kg | 6 |
| 301021 | ALPHA | LAL | Thorium-228 | 1420 | | pCi/Kg | 180 |
| 301021 | ALPHA | LAL | Thorium-230 | 1280 | | pCi/Kg | 160 |
| 301021 | ALPHA | LAL | Thorium-232 | 1260 | | pCi/Kg | 160 |
| 301021 | ALPHA | LAL | Uranium-233/234 | 0.943 | Y | pCi/g | .098 |
| 301021 | ALPHA | LAL | Uranium-235 | 0.944 | Y | pCi/g | .098 |
| 301021 | ALPHA | LAL | Uranium-238 | 0.944 | Y | pCi/g | .098 |
| 301021 | BETA | LAL | Strontium-90 | -40 | | pCi/Kg | |
| 301021 | BETA | LAL | Technetium-99 | 30 | | pCi/Kg | 180 |
| 301021 | GAMMA | LAL | Actinium-228 | 1100 | | pCi/Kg | |
| 301021 | GAMMA | LAL | Bismuth-212 | 530 | | pCi/Kg | |
| 301021 | GAMMA | LAL | Bismuth-214 | 1050 | | pCi/Kg | |
| 301021 | GAMMA | LAL | Cesium-137 | 438 | | pCi/Kg | 61 |
| 301021 | GAMMA | LAL | Cobalt 60 | 6 | | pCi/Kg | |
| 301021 | GAMMA | LAL | Lead-210 | 1500 | | pCi/Kg | |
| 301021 | GAMMA | LAL | Lead-212 | 1060 | | pCi/Kg | |
| 301021 | GAMMA | LAL | Lead-214 | 1180 | | pCi/Kg | |
| 301021 | GAMMA | LAL | Potassium-40 | 13300 | | pCi/Kg | 1600 |
| 301021 | GAMMA | LAL | Radium-223 | -50 | | pCi/Kg | |
| 301021 | GAMMA | LAL | Thallium-208 | 335 | | pCi/Kg | |
| 301021 | GAMMA | LAL | Thorium-234 | 780 | | pCi/Kg | 450 |
| 301021 | GAMMA | LAL | Uranium-235 | -72 | | pCi/Kg | 95 |
| 301021 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301021 | ICP-MS | LAL | Beryllium | 0.46 | B | mg/Kg | |
| 301021 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301021 | ICP-MS | LAL | Thallium | 0.2 | U | mg/Kg | |
| 301021 | ICP-MS | LAL | Thorium-232 | 5.4 | | mg/Kg | |
| 301021 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301021 | ICP-MS | LAL | Uranium-238 | 1 | | mg/Kg | |
| 301021 | NAA | ORN | Thorium-232 | 8.5 | | mg/Kg | |
| 301021 | NAA | ORN | Uranium-235 | 0.021 | | mg/Kg | |
| 301021 | NAA | ORN | Uranium-238 | 3.4 | | mg/Kg | |
| 301021 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 11.77 | | % | |
| 301022 | ALPHA | LAL | Thorium-228 | 1000 | | pCi/Kg | 130 |
| 301022 | ALPHA | LAL | Thorium-230 | 1000 | | pCi/Kg | 120 |
| 301022 | ALPHA | LAL | Thorium-232 | 980 | | pCi/Kg | 120 |
| 301022 | ALPHA | LAL | Uranium-233/234 | 875 | | pCi/Kg | 89 |
| 301022 | ALPHA | LAL | Uranium-235 | 65 | | pCi/Kg | 21 |
| 301022 | ALPHA | LAL | Uranium-238 | 1007 | | pCi/Kg | 96 |
| 301022 | BETA | LAL | Technetium-99 | 230 | | pCi/Kg | 210 |
| 301022 | GAMMA | LAL | Actinium-228 | 1320 | | pCi/Kg | |
| 301022 | GAMMA | LAL | Bismuth-212 | 620 | | pCi/Kg | |
| 301022 | GAMMA | LAL | Bismuth-214 | 1210 | | pCi/Kg | |
| 301022 | GAMMA | LAL | Cesium-137 | -5 | | pCi/Kg | 29 |

# Background Soils Project Analytical Data

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|---|---|---|---|---|---|---|---|
| 301022 | GAMMA | LAL | Cobalt 60 | -24 | | pCi/Kg | |
| 301022 | GAMMA | LAL | Lead-210 | 1900 | | pCi/Kg | |
| 301022 | GAMMA | LAL | Lead-212 | 1360 | | pCi/Kg | |
| 301022 | GAMMA | LAL | Lead-214 | 1320 | | pCi/Kg | |
| 301022 | GAMMA | LAL | Potassium-40 | 13500 | | pCi/Kg | 1900 |
| 301022 | GAMMA | LAL | Radium-223 | -170 | | pCi/Kg | |
| 301022 | GAMMA | LAL | Thallium-208 | 399 | | pCi/Kg | |
| 301022 | GAMMA | LAL | Thorium-234 | 2070 | | pCi/Kg | 530 |
| 301022 | GAMMA | LAL | Uranium-235 | -75 | | pCi/Kg | 70 |
| 301022 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301022 | ICP-MS | LAL | Beryllium | 0.53 | B | mg/Kg | |
| 301022 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301022 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301022 | ICP-MS | LAL | Thorium-232 | 6.4 | | mg/Kg | |
| 301022 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301022 | ICP-MS | LAL | Uranium-238 | 0.92 | | mg/Kg | |
| 301022 | NAA | ORN | Thorium-232 | 10.4 | | mg/Kg | |
| 301022 | NAA | ORN | Uranium-235 | 0.02 | | mg/Kg | |
| 301022 | NAA | ORN | Uranium-238 | 3.3 | | mg/Kg | |
| 301022 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 20.76 | | % | |
| 301023 | ALPHA | LAL | Neptunium-237 | 24 | | pCi/Kg | 24 |
| 301023 | ALPHA | LAL | Plutonium-238 | 3.1 | | pCi/Kg | 3.1 |
| 301023 | ALPHA | LAL | Plutonium-239/240 | 10.2 | | pCi/Kg | 6 |
| 301023 | ALPHA | LAL | Thorium-228 | 1390 | | pCi/Kg | 180 |
| 301023 | ALPHA | LAL | Thorium-230 | 1230 | | pCi/Kg | 160 |
| 301023 | ALPHA | LAL | Thorium-232 | 1170 | | pCi/Kg | 150 |
| 301023 | ALPHA | LAL | Uranium-233/234 | 913 | | pCi/Kg | 95 |
| 301023 | ALPHA | LAL | Uranium-235 | 31 | | pCi/Kg | 17 |
| 301023 | ALPHA | LAL | Uranium-238 | 836 | | pCi/Kg | 90 |
| 301023 | BETA | LAL | Strontium-90 | -70 | | pCi/Kg | |
| 301023 | BETA | LAL | Technetium-99 | 0 | | pCi/Kg | 190 |
| 301023 | GAMMA | LAL | Actinium-228 | 1370 | | pCi/Kg | |
| 301023 | GAMMA | LAL | Bismuth-212 | 740 | | pCi/Kg | |
| 301023 | GAMMA | LAL | Bismuth-214 | 1020 | | pCi/Kg | |
| 301023 | GAMMA | LAL | Cesium-137 | 315 | | pCi/Kg | 63 |
| 301023 | GAMMA | LAL | Cobalt 60 | -23 | | pCi/Kg | |
| 301023 | GAMMA | LAL | Lead-210 | 2450 | | pCi/Kg | |
| 301023 | GAMMA | LAL | Lead-212 | 1140 | | pCi/Kg | |
| 301023 | GAMMA | LAL | Lead-214 | 1310 | | pCi/Kg | |
| 301023 | GAMMA | LAL | Potassium-40 | 13300 | | pCi/Kg | 1800 |
| 301023 | GAMMA | LAL | Radium-223 | -20 | | pCi/Kg | |
| 301023 | GAMMA | LAL | Thallium-208 | 384 | | pCi/Kg | |
| 301023 | GAMMA | LAL | Thorium-234 | 1190 | | pCi/Kg | 470 |
| 301023 | GAMMA | LAL | Uranium-235 | 110 | | pCi/Kg | 180 |
| 301023 | ICP-MS | LAL | Antimony | 0.19 | UN | mg/Kg | |
| 301023 | ICP-MS | LAL | Beryllium | 0.4 | B | mg/Kg | |
| 301023 | ICP-MS | LAL | Cadmium | 0.19 | U | mg/Kg | |
| 301023 | ICP-MS | LAL | Thallium | 0.19 | U | mg/Kg | |
| 301023 | ICP-MS | LAL | Thorium-232 | 4.9 | | mg/Kg | |

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|---|---|---|---|---|---|---|---|
| 301023 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301023 | ICP-MS | LAL | Uranium-238 | 0.94 | | mg/Kg | |
| 301023 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 12.51 | | % | |
| 301024 | ALPHA | LAL | Thorium-228 | 1140 | | pCi/Kg | 150 |
| 301024 | ALPHA | LAL | Thorium-230 | 1030 | | pCi/Kg | 130 |
| 301024 | ALPHA | LAL | Thorium-232 | 990 | | pCi/Kg | 130 |
| 301024 | ALPHA | LAL | Uranium-233/234 | 940 | | pCi/Kg | 87 |
| 301024 | ALPHA | LAL | Uranium-235 | 99 | | pCi/Kg | 25 |
| 301024 | ALPHA | LAL | Uranium-238 | 937 | | pCi/Kg | 87 |
| 301024 | BETA | LAL | Technetium-99 | 150 | | pCi/Kg | 220 |
| 301024 | GAMMA | LAL | Actinium-228 | 1280 | | pCi/Kg | |
| 301024 | GAMMA | LAL | Bismuth-212 | 570 | | pCi/Kg | |
| 301024 | GAMMA | LAL | Bismuth-214 | 1080 | | pCi/Kg | |
| 301024 | GAMMA | LAL | Cesium-137 | 11 | | pCi/Kg | 21 |
| 301024 | GAMMA | LAL | Cobalt 60 | 9 | | pCi/Kg | |
| 301024 | GAMMA | LAL | Lead-210 | 1000 | | pCi/Kg | |
| 301024 | GAMMA | LAL | Lead-212 | 1190 | | pCi/Kg | |
| 301024 | GAMMA | LAL | Lead-214 | 1260 | | pCi/Kg | |
| 301024 | GAMMA | LAL | Potassium-40 | 12900 | | pCi/Kg | 1500 |
| 301024 | GAMMA | LAL | Radium-223 | 110 | | pCi/Kg | |
| 301024 | GAMMA | LAL | Thallium-208 | 370 | | pCi/Kg | |
| 301024 | GAMMA | LAL | Thorium-234 | 840 | | pCi/Kg | 490 |
| 301024 | GAMMA | LAL | Uranium-235 | 90 | | pCi/Kg | 140 |
| 301024 | ICP-MS | LAL | Antimony | 0.2 | UN | mg/Kg | |
| 301024 | ICP-MS | LAL | Beryllium | 0.49 | B | mg/Kg | |
| 301024 | ICP-MS | LAL | Cadmium | 0.2 | U | mg/Kg | |
| 301024 | ICP-MS | LAL | Thallium | 0.2 | B | mg/Kg | |
| 301024 | ICP-MS | LAL | Thorium-232 | 6.5 | | mg/Kg | |
| 301024 | ICP-MS | LAL | Uranium-235 | 0.02 | U | mg/Kg | |
| 301024 | ICP-MS | LAL | Uranium-238 | 0.97 | | mg/Kg | |
| 301024 | PIPETTE | UT | Grain Size Diam < .002 (clay) | 20.8 | | % | |

# Background Soils Project Analytical Data

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## Quality Control Rinsate

| Sample ID | Method | Laboratory | Analysis | Result | Qualifier | Units | Error |
|---|---|---|---|---|---|---|---|
| 101033 | BETA | LAL | Strontium-90 | -0.04 | | pCi/L | 0 |
| 101033 | GAMMA | LAL | Actinium-228 | -2 | | pCi/L | 15 |
| 101033 | GAMMA | LAL | Bismuth-212 | -9 | | pCi/L | 33 |
| 101033 | GAMMA | LAL | Bismuth-214 | 3.8 | | pCi/L | 8 |
| 101033 | GAMMA | LAL | Cesium-137 | 4.2 | | pCi/L | 2 |
| 101033 | GAMMA | LAL | Cobalt 60 | 0.6 | | pCi/L | 1 |
| 101033 | GAMMA | LAL | Lead-210 | -24 | | pCi/L | 71 |
| 101033 | GAMMA | LAL | Lead-212 | 5.2 | | pCi/L | 6 |
| 101033 | GAMMA | LAL | Lead-214 | -1.5 | | pCi/L | 7 |
| 101033 | GAMMA | LAL | Potassium-40 | 37 | | pCi/L | 49 |
| 101033 | GAMMA | LAL | Radium-223 | -10 | | pCi/L | 21 |
| 101033 | GAMMA | LAL | Radium-226 | 40 | | pCi/L | 76 |
| 101033 | GAMMA | LAL | Thallium-208 | -0.9 | | pCi/L | 4 |
| 101033 | GAMMA | LAL | Thorium-234 | -26 | | pCi/L | 46 |
| 101033 | GAMMA | LAL | Uranium-235 | 17 | | pCi/L | 18 |
| 101034 | GAMMA | LAL | Actinium-228 | -6 | | pCi/L | 15 |
| 101034 | GAMMA | LAL | Bismuth-212 | 22 | | pCi/L | 17 |
| 101034 | GAMMA | LAL | Bismuth-214 | 4.3 | | pCi/L | 8 |
| 101034 | GAMMA | LAL | Cesium-137 | 0.2 | | pCi/L | 4 |
| 101034 | GAMMA | LAL | Cobalt 60 | 0.2 | | pCi/L | 1 |
| 101034 | GAMMA | LAL | Lead-210 | 48 | | pCi/L | 78 |
| 101034 | GAMMA | LAL | Lead-212 | -32.3 | | pCi/L | 4 |
| 101034 | GAMMA | LAL | Lead-214 | 0.3 | | pCi/L | 7 |
| 101034 | GAMMA | LAL | Potassium-40 | -17 | | pCi/L | 48 |
| 101034 | GAMMA | LAL | Radium-223 | -18 | | pCi/L | 21 |
| 101034 | GAMMA | LAL | Radium-226 | 33 | | pCi/L | 75 |
| 101034 | GAMMA | LAL | Thallium-208 | -1.9 | | pCi/L | 4 |
| 101034 | GAMMA | LAL | Thorium-234 | 11 | | pCi/L | 48 |
| 101034 | GAMMA | LAL | Uranium-235 | -8 | | pCi/L | 14 |
| 101088 | ALPHA | LAL | Plutonium-238 | 0.003 | | pCi/L | 0 |
| 101088 | ALPHA | LAL | Plutonium-239/240 | 0.009 | | pCi/L | 0 |
| 101088 | GAMMA | LAL | Actinium-228 | -3 | | pCi/L | 15 |
| 101088 | GAMMA | LAL | Bismuth-212 | 13 | | pCi/L | 16 |
| 101088 | GAMMA | LAL | Bismuth-214 | 3.4 | | pCi/L | 8 |
| 101088 | GAMMA | LAL | Cesium-137 | -0.76 | | pCi/L | 0 |
| 101088 | GAMMA | LAL | Cobalt 60 | 0.5 | | pCi/L | 1 |
| 101088 | GAMMA | LAL | Lead-210 | 30 | | pCi/L | 77 |
| 101088 | GAMMA | LAL | Lead-212 | -31.4 | | pCi/L | 4 |
| 101088 | GAMMA | LAL | Lead-214 | 1.9 | | pCi/L | 7 |
| 101088 | GAMMA | LAL | Potassium-40 | -23 | | pCi/L | 48 |
| 101088 | GAMMA | LAL | Radium-223 | 8 | | pCi/L | 21 |
| 101088 | GAMMA | LAL | Radium-226 | -12 | | pCi/L | 74 |
| 101088 | GAMMA | LAL | Thallium-208 | -2 | | pCi/L | 4 |
| 101088 | GAMMA | LAL | Thorium-234 | -11 | | pCi/L | 48 |
| 101088 | GAMMA | LAL | Uranium-235 | 8 | | pCi/L | 17 |
| 101114 | BETA | LAL | Technetium-99 | -0.05 | B | pCi/L | 0 |

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|---|---|---|---|---|---|---|---|
| 101114 | GAMMA | LAL | Actinium-228 | 1 | | pCi/L | 13 |
| 101114 | GAMMA | LAL | Bismuth-212 | 12 | | pCi/L | 15 |
| 101114 | GAMMA | LAL | Bismuth-214 | -3.2 | | pCi/L | 7 |
| 101114 | GAMMA | LAL | Cesium-137 | -0.488 | | pCi/L | 0 |
| 101114 | GAMMA | LAL | Cobalt 60 | -0.86 | | pCi/L | 0 |
| 101114 | GAMMA | LAL | Lead-210 | 24 | | pCi/L | 61 |
| 101114 | GAMMA | LAL | Lead-212 | -0.6 | | pCi/L | 5 |
| 101114 | GAMMA | LAL | Lead-214 | -1.6 | | pCi/L | 6 |
| 101114 | GAMMA | LAL | Potassium-40 | 15 | | pCi/L | 39 |
| 101114 | GAMMA | LAL | Radium-223 | -10 | | pCi/L | 20 |
| 101114 | GAMMA | LAL | Thallium-208 | -2.5 | | pCi/L | 4 |
| 101114 | GAMMA | LAL | Thorium-234 | 26 | | pCi/L | 40 |
| 101114 | GAMMA | LAL | Uranium-235 | -3 | | pCi/L | 15 |
| 101115 | GAMMA | LAL | Actinium-228 | 7 | | pCi/L | 14 |
| 101115 | GAMMA | LAL | Bismuth-212 | -3 | | pCi/L | 31 |
| 101115 | GAMMA | LAL | Bismuth-214 | 0.6 | | pCi/L | 7 |
| 101115 | GAMMA | LAL | Cesium-137 | 0.6 | | pCi/L | 2 |
| 101115 | GAMMA | LAL | Cobalt 60 | -0.1 | | pCi/L | 2 |
| 101115 | GAMMA | LAL | Lead-210 | -28 | | pCi/L | 66 |
| 101115 | GAMMA | LAL | Lead-212 | 0.8 | | pCi/L | 6 |
| 101115 | GAMMA | LAL | Lead-214 | 1.5 | | pCi/L | 7 |
| 101115 | GAMMA | LAL | Potassium-40 | 6 | | pCi/L | 45 |
| 101115 | GAMMA | LAL | Radium-223 | -29.7 | | pCi/L | 2 |
| 101115 | GAMMA | LAL | Thallium-208 | -0.7 | | pCi/L | 4 |
| 101115 | GAMMA | LAL | Thorium-234 | 4 | | pCi/L | 44 |
| 101115 | GAMMA | LAL | Uranium-235 | 6 | | pCi/L | 17 |
| 101115 | ICP-MS | LAL | Antimony | 0.001 | U | mg/L | |
| 101115 | ICP-MS | LAL | Beryllium | 0.005 | U | mg/L | |
| 101115 | ICP-MS | LAL | Cadmium | 0.005 | U | mg/L | |
| 101115 | ICP-MS | LAL | Thallium | 0.005 | U | mg/L | |
| 101115 | ICP-MS | LAL | Thorium-232 | 1 | U | ug/L | |
| 101115 | ICP-MS | LAL | Uranium-235 | 1 | U | ug/L | |
| 101115 | ICP-MS | LAL | Uranium-238 | 1 | U | ug/L | |
| 301031A | GAMMA | LAL | Actinium-228 | -1 | | pCi/L | 15 |
| 301031A | GAMMA | LAL | Bismuth-212 | -9 | | pCi/L | 34 |
| 301031A | GAMMA | LAL | Bismuth-214 | 6.1 | | pCi/L | 8 |
| 301031A | GAMMA | LAL | Cesium-137 | 0.3 | | pCi/L | 2 |
| 301031A | GAMMA | LAL | Cobalt 60 | 1.5 | | pCi/L | 1 |
| 301031A | GAMMA | LAL | Lead-210 | 29 | | pCi/L | 73 |
| 301031A | GAMMA | LAL | Lead-212 | -0.5 | | pCi/L | 6 |
| 301031A | GAMMA | LAL | Lead-214 | -0.8 | | pCi/L | 7 |
| 301031A | GAMMA | LAL | Potassium-40 | 14 | | pCi/L | 49 |
| 301031A | GAMMA | LAL | Radium-223 | 2 | | pCi/L | 20 |
| 301031A | GAMMA | LAL | Radium-226 | 56 | | pCi/L | 76 |
| 301031A | GAMMA | LAL | Thallium-208 | 1.5 | | pCi/L | 4 |
| 301031A | GAMMA | LAL | Thorium-234 | -8 | | pCi/L | 46 |
| 301031A | GAMMA | LAL | Uranium-235 | 12 | | pCi/L | 18 |
| 301031B | ALPHA | LAL | Neptunium-237 | -0.0028 | | pCi/L | 0 |
| 301031B | ALPHA | LAL | Plutonium-238 | 0 | | pCi/L | 0 |

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|---|---|---|---|---|---|---|---|
| 301031B | ALPHA | LAL | Plutonium-239/240 | 0.0066 | | pCi/L | 0 |
| 301031B | ALPHA | LAL | Thorium-228 | -0.01 | | pCi/L | 0 |
| 301031B | ALPHA | LAL | Thorium-230 | 0.008 | | pCi/L | 0 |
| 301031B | ALPHA | LAL | Thorium-232 | -0.003 | | pCi/L | 0 |
| 301031B | ALPHA | LAL | Uranium-233/234 | 0.144 | | pCi/L | 0 |
| 301031B | ALPHA | LAL | Uranium-235 | 0.058 | | pCi/L | 0 |
| 301031B | ALPHA | LAL | Uranium-238 | 0.058 | | pCi/L | 0 |
| 301031B | BETA | LAL | Strontium-90 | -0.17 | | pCi/L | 0 |
| 301031B | BETA | LAL | Technetium-99 | -0.08 | B | pCi/L | 0 |
| 301031B | GAMMA | LAL | Actinium-228 | 3 | | pCi/L | 16 |
| 301031B | GAMMA | LAL | Bismuth-212 | 7 | | pCi/L | 18 |
| 301031B | GAMMA | LAL | Bismuth-214 | 4.2 | | pCi/L | 9 |
| 301031B | GAMMA | LAL | Cesium-137 | -0.3 | | pCi/L | 4 |
| 301031B | GAMMA | LAL | Cobalt 60 | 2.1 | | pCi/L | 2 |
| 301031B | GAMMA | LAL | Lead-210 | -25 | | pCi/L | 83 |
| 301031B | GAMMA | LAL | Lead-212 | -25.7 | | pCi/L | 3 |
| 301031B | GAMMA | LAL | Lead-214 | -2.9 | | pCi/L | 7 |
| 301031B | GAMMA | LAL | Potassium-40 | 20 | | pCi/L | 51 |
| 301031B | GAMMA | LAL | Radium-223 | -10 | | pCi/L | 26 |
| 301031B | GAMMA | LAL | Thallium-208 | 0 | | pCi/L | 5 |
| 301031B | GAMMA | LAL | Thorium-234 | 21 | | pCi/L | 52 |
| 301031B | GAMMA | LAL | Uranium-235 | 4 | | pCi/L | 18 |
| 301031B | ICP-MS | LAL | Antimony | 0.001 | U | mg/L | |
| 301031B | ICP-MS | LAL | Beryllium | 0.005 | U | mg/L | |
| 301031B | ICP-MS | LAL | Cadmium | 0.005 | U | mg/L | |
| 301031B | ICP-MS | LAL | Thallium | 0.005 | U | mg/L | |
| 301031B | ICP-MS | LAL | Thorium-232 | 1 | U | ug/L | |
| 301031B | ICP-MS | LAL | Uranium-235 | 1 | U | ug/L | |
| 301031B | ICP-MS | LAL | Uranium-238 | 1 | U | ug/L | |
| 301032 | ALPHA | LAL | Neptunium-237 | 0.049 | | pCi/L | 0 |
| 301032 | ALPHA | LAL | Plutonium-238 | -0.0019 | | pCi/L | 0 |
| 301032 | ALPHA | LAL | Plutonium-239/240 | 0.017 | | pCi/L | 0 |
| 301032 | ALPHA | LAL | Thorium-228 | -0.034 | | pCi/L | 0 |
| 301032 | ALPHA | LAL | Thorium-230 | 0.011 | | pCi/L | 0 |
| 301032 | ALPHA | LAL | Thorium-232 | -0.021 | | pCi/L | 0 |
| 301032 | ALPHA | LAL | Uranium-233/234 | 0.016 | | pCi/L | 0 |
| 301032 | ALPHA | LAL | Uranium-235 | 0.01 | | pCi/L | 0 |
| 301032 | ALPHA | LAL | Uranium-238 | 0.008 | | pCi/L | 0 |
| 301032 | BETA | LAL | Strontium-90 | 0 | | pCi/L | 0 |
| 301032 | BETA | LAL | Technetium-99 | -0.1 | B | pCi/L | 0 |
| 301032 | GAMMA | LAL | Actinium-228 | 4 | | pCi/L | 12 |
| 301032 | GAMMA | LAL | Bismuth-212 | -8 | | pCi/L | 25 |
| 301032 | GAMMA | LAL | Bismuth-214 | -1.2 | | pCi/L | 6 |
| 301032 | GAMMA | LAL | Cesium-137 | -0.3 | | pCi/L | 1 |
| 301032 | GAMMA | LAL | Cobalt 60 | -0.3 | | pCi/L | 2 |
| 301032 | GAMMA | LAL | Lead-210 | -2 | | pCi/L | 55 |
| 301032 | GAMMA | LAL | Lead-212 | 1.1 | | pCi/L | 5 |
| 301032 | GAMMA | LAL | Lead-214 | -1.2 | | pCi/L | 5 |
| 301032 | GAMMA | LAL | Potassium-40 | 10 | | pCi/L | 38 |

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|---|---|---|---|---|---|---|---|
| 301032 | GAMMA | LAL | Radium-223 | -36 | | pCi/L | 3 |
| 301032 | GAMMA | LAL | Thallium-208 | -1.3 | | pCi/L | 3 |
| 301032 | GAMMA | LAL | Thorium-234 | 6 | | pCi/L | 37 |
| 301032 | GAMMA | LAL | Uranium-235 | 2 | | pCi/L | 14 |
| 301032 | ICP-MS | LAL | Antimony | 0.001 | U | mg/L | |
| 301032 | ICP-MS | LAL | Beryllium | 0.005 | U | mg/L | |
| 301032 | ICP-MS | LAL | Cadmium | 0.005 | U | mg/L | |
| 301032 | ICP-MS | LAL | Thallium | 0.005 | U | mg/L | |
| 301032 | ICP-MS | LAL | Thorium-232 | 1 | U | ug/L | |
| 301032 | ICP-MS | LAL | Uranium-235 | 1 | U | ug/L | |
| 301032 | ICP-MS | LAL | Uranium-238 | 1 | U | ug/L | |
| 301033 | ALPHA | LAL | Neptunium-237 | 0 | | pCi/L | 0 |
| 301033 | ALPHA | LAL | Plutonium-238 | -0.0019 | | pCi/L | 0 |
| 301033 | ALPHA | LAL | Plutonium-239/240 | 0.01 | | pCi/L | 0 |
| 301033 | ALPHA | LAL | Thorium-228 | 0.016 | | pCi/L | 0 |
| 301033 | ALPHA | LAL | Thorium-230 | -0.002 | | pCi/L | 0 |
| 301033 | ALPHA | LAL | Thorium-232 | -0.005 | | pCi/L | 0 |
| 301033 | ALPHA | LAL | Uranium-233/234 | 0.135 | | pCi/L | 0 |
| 301033 | ALPHA | LAL | Uranium-235 | 0.006 | | pCi/L | 0 |
| 301033 | ALPHA | LAL | Uranium-238 | 0.017 | | pCi/L | 0 |
| 301033 | BETA | LAL | Strontium-90 | 0.04 | | pCi/L | 0 |
| 301033 | BETA | LAL | Technetium-99 | -0.08 | B | pCi/L | 0 |
| 301033 | GAMMA | LAL | Actinium-228 | -1 | | pCi/L | 12 |
| 301033 | GAMMA | LAL | Bismuth-212 | 13 | | pCi/L | 13 |
| 301033 | GAMMA | LAL | Bismuth-214 | -1 | | pCi/L | 6 |
| 301033 | GAMMA | LAL | Cesium-137 | 0.6 | | pCi/L | 3 |
| 301033 | GAMMA | LAL | Cobalt 60 | -1.67 | | pCi/L | 0 |
| 301033 | GAMMA | LAL | Lead-210 | -5 | | pCi/L | 56 |
| 301033 | GAMMA | LAL | Lead-212 | -18.2 | | pCi/L | 3 |
| 301033 | GAMMA | LAL | Lead-214 | -5.5 | | pCi/L | 5 |
| 301033 | GAMMA | LAL | Potassium-40 | 10 | | pCi/L | 35 |
| 301033 | GAMMA | LAL | Radium-223 | -46.2 | | pCi/L | 4 |
| 301033 | GAMMA | LAL | Thallium-208 | -1.1 | | pCi/L | 3 |
| 301033 | GAMMA | LAL | Thorium-234 | 22 | | pCi/L | 37 |
| 301033 | GAMMA | LAL | Uranium-235 | -1 | | pCi/L | 14 |
| 301033 | ICP-MS | LAL | Antimony | 0.005 | B | mg/L | |
| 301033 | ICP-MS | LAL | Beryllium | 0.005 | U | mg/L | |
| 301033 | ICP-MS | LAL | Cadmium | 0.005 | U | mg/L | |
| 301033 | ICP-MS | LAL | Thallium | 0.005 | U | mg/L | |
| 301033 | ICP-MS | LAL | Thorium-232 | 1 | U | ug/L | |
| 301033 | ICP-MS | LAL | Uranium-235 | 1 | U | ug/L | |
| 301033 | ICP-MS | LAL | Uranium-238 | 1 | U | ug/L | |
| 301034 | ALPHA | LAL | Neptunium-237 | 0.044 | | pCi/L | 0 |
| 301034 | ALPHA | LAL | Plutonium-238 | 0 | | pCi/L | 0 |
| 301034 | ALPHA | LAL | Plutonium-239/240 | 0.009 | | pCi/L | 0 |
| 301034 | ALPHA | LAL | Thorium-228 | -0.019 | | pCi/L | 0 |
| 301034 | ALPHA | LAL | Thorium-230 | -0.004 | | pCi/L | 0 |
| 301034 | ALPHA | LAL | Thorium-232 | -0.008 | | pCi/L | 0 |
| 301034 | ALPHA | LAL | Uranium-233/234 | 0.13 | | pCi/L | 0 |

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|---|---|---|---|---|---|---|---|
| 301034 | ALPHA | LAL | Uranium-235 | 0.021 | | pCi/L | 0 |
| 301034 | ALPHA | LAL | Uranium-238 | 0.084 | | pCi/L | 0 |
| 301034 | BETA | LAL | Strontium-90 | -0.07 | | pCi/L | 0 |
| 301034 | BETA | LAL | Technetium-99 | -0.02 | B | pCi/L | 0 |
| 301034 | GAMMA | LAL | Actinium-228 | 3 | | pCi/L | 11 |
| 301034 | GAMMA | LAL | Bismuth-212 | -1 | | pCi/L | 25 |
| 301034 | GAMMA | LAL | Bismuth-214 | 8.4 | | pCi/L | 6 |
| 301034 | GAMMA | LAL | Cesium-137 | 2.4 | | pCi/L | 1 |
| 301034 | GAMMA | LAL | Cobalt 60 | -2.26 | | pCi/L | 0 |
| 301034 | GAMMA | LAL | Lead-210 | -5 | | pCi/L | 54 |
| 301034 | GAMMA | LAL | Lead-212 | -0.9 | | pCi/L | 5 |
| 301034 | GAMMA | LAL | Lead-214 | 0.9 | | pCi/L | 5 |
| 301034 | GAMMA | LAL | Potassium-40 | 12 | | pCi/L | 38 |
| 301034 | GAMMA | LAL | Radium-223 | -25.2 | | pCi/L | 2 |
| 301034 | GAMMA | LAL | Thallium-208 | 1.8 | | pCi/L | 3 |
| 301034 | GAMMA | LAL | Thorium-234 | 11 | | pCi/L | 36 |
| 301034 | GAMMA | LAL | Uranium-235 | 7 | | pCi/L | 14 |
| 301034 | ICP-MS | LAL | Antimony | 0.001 | U | mg/L | |
| 301034 | ICP-MS | LAL | Beryllium | 0.005 | U | mg/L | |
| 301034 | ICP-MS | LAL | Cadmium | 0.005 | U | mg/L | |
| 301034 | ICP-MS | LAL | Thallium | 0.005 | U | mg/L | |
| 301034 | ICP-MS | LAL | Thorium-232 | 1 | U | ug/L | |
| 301034 | ICP-MS | LAL | Uranium-235 | 1 | U | ug/L | |
| 301034 | ICP-MS | LAL | Uranium-238 | 1 | U | ug/L | |
| 301035 | ALPHA | LAL | Neptunium-237 | 0.028 | | pCi/L | 0 |
| 301035 | ALPHA | LAL | Plutonium-238 | -0.0019 | | pCi/L | 0 |
| 301035 | ALPHA | LAL | Plutonium-239/240 | 0.0039 | | pCi/L | 0 |
| 301035 | ALPHA | LAL | Thorium-228 | -0.026 | | pCi/L | 0 |
| 301035 | ALPHA | LAL | Thorium-230 | 0.007 | | pCi/L | 0 |
| 301035 | ALPHA | LAL | Thorium-232 | -0.0074 | | pCi/L | 0 |
| 301035 | ALPHA | LAL | Uranium-233/234 | 0.212 | | pCi/L | 0 |
| 301035 | ALPHA | LAL | Uranium-235 | 0.073 | | pCi/L | 0 |
| 301035 | ALPHA | LAL | Uranium-238 | 0.041 | | pCi/L | 0 |
| 301035 | BETA | LAL | Strontium-90 | 0.13 | | pCi/L | 0 |
| 301035 | BETA | LAL | Technetium-99 | 0.54 | B | pCi/L | 0 |
| 301035 | GAMMA | LAL | Actinium-228 | 5 | | pCi/L | 12 |
| 301035 | GAMMA | LAL | Bismuth-212 | 10 | | pCi/L | 13 |
| 301035 | GAMMA | LAL | Bismuth-214 | -10.5 | | pCi/L | 1 |
| 301035 | GAMMA | LAL | Cesium-137 | 0.5 | | pCi/L | 3 |
| 301035 | GAMMA | LAL | Cobalt 60 | -1.4 | | pCi/L | 1 |
| 301035 | GAMMA | LAL | Lead-210 | -34 | | pCi/L | 57 |
| 301035 | GAMMA | LAL | Lead-212 | 1 | | pCi/L | 5 |
| 301035 | GAMMA | LAL | Lead-214 | -3.4 | | pCi/L | 5 |
| 301035 | GAMMA | LAL | Potassium-40 | 22 | | pCi/L | 37 |
| 301035 | GAMMA | LAL | Radium-223 | -40 | | pCi/L | 4 |
| 301035 | GAMMA | LAL | Thallium-208 | 1 | | pCi/L | 3 |
| 301035 | GAMMA | LAL | Thorium-234 | 17 | | pCi/L | 38 |
| 301035 | GAMMA | LAL | Uranium-235 | -4 | | pCi/L | 14 |
| 301035 | ICP-MS | LAL | Antimony | 0.002 | B | mg/L | |

# Background Soils Project Analytical Data

3/10/97

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 301035 | ICP-MS | LAL | Beryllium | 0.001 | U | mg/L | |
| 301035 | ICP-MS | LAL | Cadmium | 0.001 | U | mg/L | |
| 301035 | ICP-MS | LAL | Thallium | 0.001 | U | mg/L | |
| 301035 | ICP-MS | LAL | Thorium-232 | 1 | U | ug/L | |
| 301035 | ICP-MS | LAL | Uranium-235 | 0.1 | U | ug/L | |
| 301035 | ICP-MS | LAL | Uranium-238 | 1 | U | ug/L | |
| 301062 | ALPHA | LAL | Neptunium-237 | 0.028 | | pCi/L | 0 |
| 301062 | ALPHA | LAL | Plutonium-238 | 0.008 | | pCi/L | 0 |
| 301062 | ALPHA | LAL | Plutonium-239/240 | 0.004 | | pCi/L | 0 |
| 301062 | ALPHA | LAL | Thorium-228 | -0.007 | | pCi/L | 0 |
| 301062 | ALPHA | LAL | Thorium-230 | -0.01 | | pCi/L | 0 |
| 301062 | ALPHA | LAL | Thorium-232 | -0.002 | | pCi/L | 0 |
| 301062 | ALPHA | LAL | Uranium-233/234 | 0.028 | | pCi/L | 0 |
| 301062 | ALPHA | LAL | Uranium-235 | 0.012 | | pCi/L | 0 |
| 301062 | ALPHA | LAL | Uranium-238 | 0.01 | | pCi/L | 0 |
| 301062 | BETA | LAL | Strontium-90 | 0.09 | | pCi/L | 0 |
| 301062 | BETA | LAL | Technetium-99 | -0.16 | B | pCi/L | 0 |
| 301062 | GAMMA | LAL | Actinium-228 | 5 | | pCi/L | 12 |
| 301062 | GAMMA | LAL | Bismuth-212 | -5 | | pCi/L | 26 |
| 301062 | GAMMA | LAL | Bismuth-214 | -2.8 | | pCi/L | 6 |
| 301062 | GAMMA | LAL | Cesium-137 | -0.7 | | pCi/L | 1 |
| 301062 | GAMMA | LAL | Cobalt 60 | -1.71 | | pCi/L | 0 |
| 301062 | GAMMA | LAL | Lead-210 | 13 | | pCi/L | 57 |
| 301062 | GAMMA | LAL | Lead-212 | -23.2 | | pCi/L | 2 |
| 301062 | GAMMA | LAL | Lead-214 | 0.9 | | pCi/L | 5 |
| 301062 | GAMMA | LAL | Potassium-40 | 12 | | pCi/L | 39 |
| 301062 | GAMMA | LAL | Radium-223 | -13.5 | | pCi/L | 1 |
| 301062 | GAMMA | LAL | Thallium-208 | 0.4 | | pCi/L | 3 |
| 301062 | GAMMA | LAL | Thorium-234 | 15 | | pCi/L | 38 |
| 301062 | GAMMA | LAL | Uranium-235 | 9 | | pCi/L | 15 |
| 301062 | ICP-MS | LAL | Antimony | 0.001 | B | mg/L | |
| 301062 | ICP-MS | LAL | Beryllium | 0.005 | U | mg/L | |
| 301062 | ICP-MS | LAL | Cadmium | 0.005 | U | mg/L | |
| 301062 | ICP-MS | LAL | Thallium | 0.005 | U | mg/L | |
| 301062 | ICP-MS | LAL | Thorium-232 | 1 | U | ug/L | |
| 301062 | ICP-MS | LAL | Uranium-235 | 1 | U | ug/L | |
| 301062 | ICP-MS | LAL | Uranium-238 | 1 | U | ug/L | |

# APPENDIX E

# MEMO OF UNDERSTANDING ON APPROACH TO VERIFICATION AND VALIDATION

# Radionuclide Data Assessment Approach for the Paducah Background Soils Project

October 3, 1996

To ensure reliable data in a timely manner, the Paducah Background Soils Project plans to conduct a contract compliance screen and data assessment concurrently on the radionuclide data. The compliance screen will be done in accordance with the prepared laboratory Statement of Work and the checklists included in the Environmental Restoration Procedure number ERWM/ER-P2209, Radiochemical Data Verification and Validation.

The data assessment will be done by the lead investigator on the project using Section 9 of the Project Work Plan and the approach describe in this document. When an outlier is identified, the project will obtain the data package that includes the outlier and the data validated according to the above ER procedure.

## Validation Approach

The radionuclide data generated for the Paducah Background Soils Project will be assessed using a three pronged approach.

1. Contract Compliance Screen
2. Data Assessment for Reasonability (described below)
3. Outliers identified from either (1) or (2) will be validated according to ERWM/ER-P2209 Radiological Data Verification and Validation procedure.

## Contract Compliance Screen

The project analytical coordinator will perform the screen by reviewing the received data packages against the submitted Analytical Statement of Work. The screen will include reviewing the data package for a complete set of deliverables and ensure that the appropriate detection limits were used by the laboratory. In addition, the screen will assess some quality control (QC) measures such as spikes, duplicates and laboratory control samples. The criteria for review of these QC measures is detailed in ERWM/ER-P2209 Radiological Data Verification and Validation procedure.

## Data Assessment

The data assessment will be conducted by reviewing the thorium and uranium alpha and gamma spectroscopy results. Each isotope will be assessed by comparing the results of the gamma-radionuclide daughter products to the results of the alpha analysis of the parent radionuclides. The results of the Uranium and Thorium alpha analysis will be used by the project for decision making purposes.

Uranium

The assumption for uranium is that Uranium-238 will be in equilibrium with Thorium-234 and Protactinium-234m and Uranium-235 will be in equilibrium with Thorium-231. The half lives of Thorium-231, Thorium-234 and Protactinium-234m are 25.52 hours, 24.10 days and 1.17 minutes respectively.

The samples collected for Uranium isotopic (U-234, 235 and 238) analysis will be analyzed by alpha spectroscopy. The data will be assessed:

1. By calculating activity ratio of U-235/ U-238 and U-234/ U-238 from alpha spectroscopy with expected results of 0.007 to 1 gram weight basis and a one to one activity basis, respectively.
2. By calculating ratio of U-235/Pa-234m (U-238) from the gamma spectroscopy results.
3. By comparing the alpha results with the gamma results.
4. By comparing gamma results of uranium with uranium decay products (Bi-214, Pb-214) to demonstrate secular equilibrium.

Since the Protactinium-234m and Thorium-234 should be in equilibrium with Uranium-238 and -235, any results where the daughters activity are greater than 50% difference with the parent will be considered an outlier (2 sigma error will be considered when evaluating the 50% criteria) and the data associated with that sample delivery group (SDG) will be validated according to the Radiological Data Verification and Validation procedure.

Thorium

The assumption for thorium is that the Thorium-232 will be in equilibrium with its daughter Actinium-228 and Thorium-228. The half lives of Actinium-228 and Thorium-228 are 6.13 hours and 1.91 years respectively. Depending on the percentage of natural uranium in the sample, Thorium-230 will not necessarily be in equilibrium with its daughters. However, the chemical separation and isotopic analysis of thorium occurs in the same analytical process and the thorium isotopes are analyzed on the same system, it is assumed that if the results are satisfactory for Thorium-232 and Thorium-228, then the results are satisfactory for Thorium-230.

Thorium-228, -230 and-232 will be analyzed by alpha spectroscopy. The results of the alpha spectroscopy will be assessed comparing the results of the gamma daughters to the alpha parent. The Actinium-228 is in equilibrium with Thorium-228. Therefore, any Actinium-228 results that are greater than 50% (2 sigma error will be considered when evaluating the 50% criteria) the Thorium-228 alpha spectroscopy results will be considered questionable and validated according to the Radiological Data Verification and Validation procedure.

Thorium-228 and Thorium-232 are also in equilibrium. Therefore, any Thorium-232 result that is more than 50% (2 sigma error will be considered when evaluating the 50% criteria) the Thorium-228 result will be considered questionable and then the results will be validated according to the Radiological Data Verification and Validation procedure. The thorium data will

be assessed:

1. By calculating the activity ratio of Th-228/Th-232 from alpha spectroscopy results.
2. By comparing the gamma spectroscopy results by ratio of Th-232 to Ac-228.
3. By comparing the results from alpha spectroscopy to gamma spectroscopy.

**Data Validation**

The project will validate only the radionuclide data found as an outlier from the contract compliance screen and/or data assessment. The data found as outliers will be validated according to the ERWM/ER-P2209 Radiological Data Verification and Validation procedure.

| | |
|---|---|
| L. Bishop, DOE-ORO-ER | 10-7-96 Date |
| T. L. Hatmaker-ORNL, Project Analytical Coordinator | 10-7-96 Date |
| T. M. Koepp-ORNL, Project QA/QC Oversight Manager | 10/3/96 Date |
| S. Y. Lee-ORNL, Technical Coordinator | 10/31 96 Date |
| C. W. Francis-ORNL, Project Manager | 10/3/96 Date |

COMMENTS:

# APPENDIX F

# ANALYTICAL DATA QUALIFIERS AND VALIDATION QUALIFIERS

**Table F.1. Data qualifiers for laboratory analyses**

| Qualifier | Definition |
|---|---|
| B | For Inorganic CLP Analyses Only - Reported value is less than the contract required detection limit (CRDL) but greater than or equal to the instrument detection limit (IDL).<br>For Radiochemical Analyses - Any concentration that was detected in the associated method blank at a concentration [was] greater than the reporting detection limit (RDL). |
| C | For Routine, Non-CLP Inorganic Analyses - Any constituent that was also detected in the associated blank whose concentration was greater than the reporting detection limit (RDL).<br>For Radiochemical Analyses - The minimum detectable activity exceeded the RDL due to the residue weight limitation forcing a volume reduction. |
| D | For Inorganic Analyses - Presence of high level of interfering constituents required dilution of sample which increased the RDL by the dilution factor.<br>For Radiochemical Analyses - Constituent detected in the diluted sample. |
| E | For Inorganic Analyses - Estimated value due to presence of interference.<br>For Radiochemical Analyses - Constituent concentration exceeded the calibration or attention curve range. |
| F | For Radiochemical (Alpha Spectrometry only) - Full width half max. exceeded the acceptance limits. |
| H | Sample analysis performed outside of method-or client-specified maximum holding time requirement. |
| M | For Inorganic CLP Analyses only - Duplicate injection precision criterion was not present. |
| N | For Inorganic Analyses - Matrix spike recovery exceeded acceptance limits. |
| S | For Inorganic Analyses - Reported value was determined from the method of standard addition. |
| U | For Inorganic CLP Analyses only - Constituent was analyzed for but not detected (sample quantification must be corrected for dilution and percent moisture). |
| W | For Inorganic AAS Analyses only - Post-digestion spike for Furnace AAS did not met acceptance criteria and sample absorbance is less than 50% of spike absorbance. |
| Y | For Radiochemical Analyses - Chemical yield exceeded acceptance limits. |
| * | For Inorganic Analyses - Relative percent difference (RPD) for duplicate analysis exceeded acceptance limits. |
| + | For Inorganic Analyses - Correlation coefficient (r) for the MSA is less than 0.995. |

**Table F.2. Data validation qualifiers and reason codes[a]**

| Qualifiers | Reason Code |
|---|---|
| U | Analyte compound or nuclide considered not detected above the reported detection limit |
| J | Analyte compound or nuclide identified; the associated numerical value is approximated |
| UJ | Analyte, compound or nuclide not detected above the reported detection limit, and the reported detection limit is approximated due to quality deficiency |
| NJ | Presumptively present at an estimated quantity (use with TIC only) |
| R | Result is not usable for its intended purpose |
| = | "Equals" sign, indicates that no qualifier is necessary |

[a]ERWM/ER-P209, Rev. 0, Appendix E, Organic, Inorganic, and Radiological Analytical Data, Reason codes must be used with all qualifiers placed on analytical data.

# APPENDIX G

# OTHER STATISTICAL ANALYSES

# Other Statistical Analyses

Other statistical analyses were performed (1) to investigate correlations between analyte concentrations and clay content, (2) to compare lab and spatial error variability, (3) to compare methods (alpha, beta, gamma, IC-PMS, and NAA), and (4) to check uranium isotopic ratios.

## G.1 Clay correlations

The association of clay with Be, $^{40}K$, and $^{238}U$ was examined by computing correlation statistics for clay with these analytes. Significant correlations were found for beryllium (0.73, p=0.0001) and Uranium-238 (0.43, p=0.001), but not $^{40}K$. The correlation of clay with $^{238}U$ is illustrated in Fig. G.1.

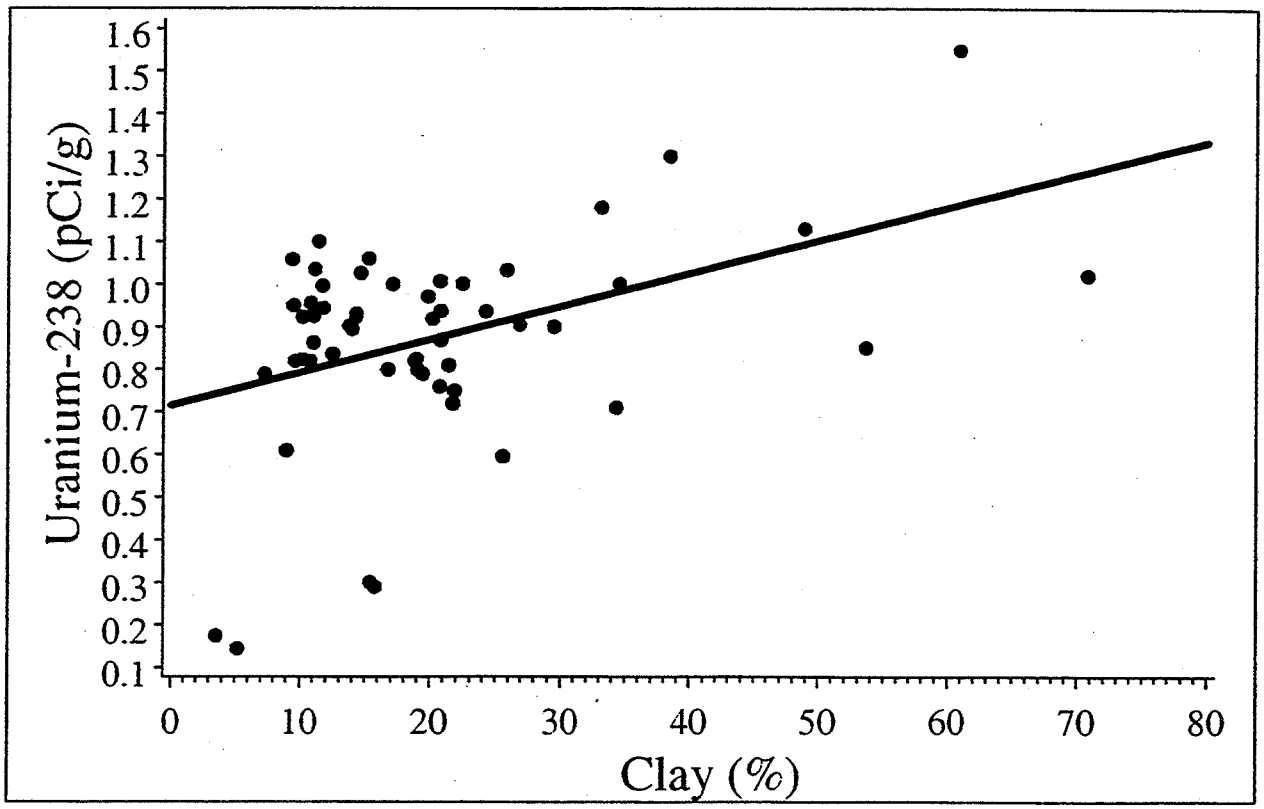


**Fig. G.1. Correlation between 238U and clay content (surface soils and hydrogeologic units included).**

## G.2 Lab and Spatial Variability

As discussed in Sect. 3.7, lab and spatial variances can be estimated from mean square errors (MSEs) computed from the Paducah background data. For example, the following variance estimates were obtained for alpha $^{238}$U:

| N | Det | Lab MSE | Lab Df | Spa. MSE | Spa. Df | MSE Ratio Spa./Lab |
|---|---|---|---|---|---|---|
| 15 | 15 | .00172 | 6 | .0067 | 4.55 | 3.88 |

These estimates can be used to compute the potential savings with composite samples over ordinary noncomposites. We illustrate this point here for $^{238}$U. The advantage of compositing is also discussed in the EPA's *Soil Screening Guidance* (EPA 1996).

The variance of a mean of n composite samples, each of composite order k is $(\sigma_L^2 + \sigma_S^2/k)/n$. Suppose that the cost per lab analysis is $C_L$ and the cost per field sample is $C_S$. Then the total cost is $nC_L + knC_S$. The method of Lagrange Multipliers can be applied to find the k that minimizes this variance subject to a bound on the fixed total cost of sampling and laboratory analysis. The solution is

$$k = \left( \frac{C_L \times \sigma_S^2}{C_S \times \sigma_L^2} \right)^{1/2}.$$

So for the alpha $^{238}$U, k is about $(3.88 \times C_L/C_S)^{1/2}$. Because of accounting questions, field sampling costs can be difficult to estimate, but generally $C_L > C_S$. If $C_L = C_S$, this analysis suggests that k=2 is a proper level for compositing for $^{238}$U. Therefore, the proper k is two or more, depending on the actual relative cost.

## G.3 Methods Comparisons

Because several analytes were analyzed by one or more methods (ICP-MS, alpha, beta, or gamma spectrometry, or NAA), for those anaytes, the methods themselves can be compared. This is done in the following table for $^{232}$Th, $^{235}$U, and $^{238}$U, for both ratios and differences. The methods are compared by testing for differences other than zero or ratios other than one, using ordinary t-tests.

PGDP Background Soils—Methods Comparison

| Analyte | Diff (pCi/g) or Ratio | N | Mean | Std. Err. | t-Statistic | Sig. Level |
|---|---|---|---|---|---|---|
| Thorium-232 | Alpha-ICP | 56 | 0.410 | 0.020 | 20.1 | .0000 |
| | Alpha-NAA | 28 | 0.060 | 0.023 | 2.6 | .0134 |
| | ICP-NAA | 28 | -0.324 | 0.021 | -15.5 | .0000 |
| | Alpha/ICP | 56 | 1.712 | 0.040 | 18.0 | .0000 |
| | Alpha/NAA | 28 | 1.062 | 0.025 | 2.5 | .0206 |
| | ICP/NAA | 28 | 0.643 | 0.017 | -21.2 | .0000 |
| Uranium-235 | Alpha-NAA | 28 | 0.014 | 0.004 | 3.4 | .0023 |
| | Alpha/NAA | 28 | 1.500 | 0.153 | 3.3 | .0029 |
| Uranium-238 | Alpha-ICP | 55 | 0.557 | 0.018 | 31.0 | .0000 |
| | Alpha-NAA | 28 | -0.032 | 0.024 | -1.3 | .2052 |
| | ICP-NAA | 27 | -0.594 | 0.036 | -16.4 | .0000 |
| | Alpha/ICP | 55 | 2.839 | 0.072 | 25.6 | .0000 |
| | Alpha/NAA | 28 | 0.998 | 0.030 | -0.1 | .9338 |
| | ICP/NAA | 27 | 0.352 | 0.018 | -35.4 | .0000 |

This table demonstrates that the analytical method has statistically significant and appreciable effects on analytical results. The method differences are also illustrated in Figs. 3.13, 3.14, and 3.15.

## G.4 Isotopic Ratios

Isotopic ratios were examined graphically to screen for outliers. In addition, the relative activities of $^{234, 235, \text{and } 238}U$ are of particular interest because they indicate enrichment or depletion from natural uranium. The relative activities for each sample point are plotted in Fig. 3.2. The location of each point is the weighted average of the coordinates of the vertices of an equilateral triangle, each coordinate representing 100% of one of $^{234, 235, \text{or } 238}U$. The 100% vertices are not shown, however, to keep the plot on a reasonable scale.

The relative activities are compared to nominal natural values (.4960, .0227, .4813) in the following table.

Comparisons of Uranium Proportion Activities with Nominal

| Variable | Mean Difference | Std Error | Prob>\|T\| |
|---|---|---|---|
| U-234 | -0.0190 | 0.00333 | 0.0001 |
| U-235 | 0.0053 | 0.00159 | 0.0028 |
| U-238 | 0.0137 | 0.00304 | 0.0002 |

These results seem to apply equally to all series and horizons: The surface results do not show any significant differences in the differences (from nominal) with series or horizon. (Analysis of variance significance levels for these comparisons are .79, .95, and .56, for $^{234}U$, $^{235}U$, and $^{238}U$.)

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