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Rev. 0

Cleanup Verification Package for the 116-B-13 South Sludge Trench

Prepared for the U.S. Department of Energy by Bechtel Hanford, Inc.

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EXECUTIVE SUMMARY

E1.0 INTRODUCTION

The cleanup verification package for the 116-B-13 South Sludge Trench (also known as the 107-B South Sludge Trench) documents the completion of cleanup activities at the site. The 116-B-13 South Sludge Trench is hereinafter referred to as the 116-B-13 site. The 116-B-13 South Sludge Trench site is located within the 100-BC-1 Operable Unit in the 100 Areas of the Hanford Site in southeastern Washington State. Remedial action at this site was performed in accordance with remedial action objectives and goals established by the U.S. Environmental Protection Agency and the Washington State Department of Ecology, in concurrence with the U.S. Department of Energy, Richland Operations Office. The selected remedial action included (1) excavating the site to the extent required to meet specified soil cleanup levels, (2) disposing of contaminated excavation materials at the Environmental Restoration Disposal Facility at the 200 Areas of the Hanford Site, and (3) backfilling the site with clean soil to adjacent grade elevations. The excavation and disposal activities have been completed. The site is currently an open excavation with sloping walls. The exposed surfaces have all been sampled and analyzed. The site will be backfilled in the near furture.

The 116-B-13 site, commonly known as the 107-B South Sludge Trench, operated in 1952. The site is located south of the southeast corner of the 107-B Retention Basin. The site dimensions are 15.2 m (50 ft) long, 15.2 m (50 ft) wide, and 3 m (10 ft) deep. This site was used to dispose of sludge removed from the 107-B Retention Basin.

This site and the 116-B-14 site were associated with maintenance cleanout of the 116-B-11 (107B) Retention Basin, which was constructed in 1944. The 116-B-11 Retention Basin held 100-B Reactor effluent water for a brief time, allowing radioactive decay and thermal cooling to occur before water was discharged into the Columbia River. There is no validation from available records that this sludge pit directly received any regular and/or high-volume liquid effluent wastes. After its use, the waste site was covered with about 1.83 m (6 ft) of soil.

Because the land use of the 100 Areas is not yet defined, the remedial actions were performed so they would not preclude any future land uses at the site. A rural residential exposure scenario was assumed in calculating cleanup levels. The extent of excavation was determined by remedial action goals for direct exposure, protection of groundwater, and protection of surface waters (including the Columbia River). For each point of compliance, specific remedial action goals were established to identify radionuclide and nonradionuclide contaminants of concern (COCs).

Field sampling, laboratory testing, and analyses of the soil were performed to verify attainment of the remedial action goals.

E2.0 RESULTS

Results of the sampling, testing, and analyses for the 116-B-13 site cleanup indicate that all remedial action objectives and goals for direct exposure, protection of groundwater, and protection of surface waters (including the Columbia River) have been met (see Table ES-1).

E2.1 DIRECT EXPOSURE SOIL CLEANUP STANDARDS

E2.1.1 Radionuclides

The maximum dose rate predicted from the RESidual RADioactivity Dose Assessment Model (RESRAD) is 2.4 mrem/yr at present and decreases to 0.03 mrem/yr in 1,000 years. The total dose rate in 19 years (the year 2018) is estimated to be 1.12 mrem/yr. The actual dose at the surface of the waste site will be considerably less than these calculations because the site will be backfilled with 4.3 m (14.11 ft) of clean backfill. All dose rates are below the 15 mrem/yr above background limit.

Table ES-1. Summary of Cleanup Verification Results for the 116-B-13 South Sludge Trench.

Regulatory Requirement	Remedial Action Goals (RAGs)	Results	Remedial Action Objectives Attained?	Ref.
Direct Exposure – Radionuclides	1. Attain 15 mrem/yr dose rate above background over 1,000 years.	1. Maximum dose calculated by RESRAD is 2.4 mrem/yr.	Yes	a
Direct Exposure – Nonradionuclides	1. Attain individual COC RAGs.	1. All individual COC concentrations are below the RAGs.	Yes	b
Meet Nonradionuclide Risk Requirements	1. Hazard quotient ratio of <1 for noncarcinogens.	1. All hazard quotient ratios are below 1.	Yes	b
	2. Cumulative hazard index ratio of <1 for noncarcinogens.	2. 0.007		b
	3. Excess cancer risk of $<1 \times 10^{-6}$ for individual carcinogens.	3. Excess cancer risk for individual carcinogens are all less than 1×10^{-6}.		b
	4. Attain a cumulative excess cancer risk of $<1 \times 10^{-5}$ for carcinogens.	4. Cumulative excess cancer risk is 7.5×10^{-11}.		b
Groundwater/River Protection – Radionuclides	1. Attain single COC groundwater and river RAGS.	1. All single COC groundwater and river RAGs have been attained.	Yes	b
	2. Attain National Primary Drinking Water Standards: 4 mrem/yr (beta/gamma) dose to target receptor/organs.	2. All organ specific doses are well below the 4 mrem/yr dose limit.		c
	3. Meet National Primary Drinking Water Standards: 15 pCi/L (alpha activity).	3. The alpha activity is 0 pCi/L for all years.		c
Groundwater/River Protection – Nonradionuclides	1. Attain individual nonradionuclide groundwater and river cleanup requirements.	1. All the groundwater and river RAGs have been attained.	Yes	a,b
Other Supporting Information	1. The maximum excess cancer risk from radionuclides (calculated via RESRAD modeling) is 1.95×10^{-5} at present.			a
	2. Sample variance calculation.			d
	3. Sample location design			e

[a] *RESRAD Calculations Supporting Closeout of the 116-B-13 Remediation Site*, Calculation No. 0100B-CA-N0009, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.
[b] *116-B-13 95% UCL Calculations for Compliance with Cleanup Standards*, Calculation No. 0100B-CA-V0056, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.
[c] *116-B-13 Comparison to Drinking Water Standards*, Calculation No. 0100B-CA-V0041, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.
[d] *116-B-13 Variance Calculation*, Calculation No. 0100B-CA-V0023, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.
[e] *116-B-13 Shallow Zone Sampling Locations*, Calculation No. 0100B-CA-V0024, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

Because of radioactive decay, the risk associated with radionuclides decreases over time. The total excess cancer risk for radionuclides was calculated by the RESRAD model. Based on RESRAD results, the total excess cancer risk is largest, 1.95×10^{-5}, at present and decreases to 8.39×10^{-8} in 1,000 years. The radionuclide risk in 19 years (the year 2018) is estimated at 9.12×10^{-6}.

E2.1.2 Nonradionuclides

The nonradionuclide COCs are total and hexavalent chromium, mercury, and lead. All concentrations are below the remedial action goals.

E2.1.3 Noncarcinogenic Risk

The individual COC and cumulative noncarcinogenic risk ratios are well below the remedial action goal of a hazard quotient of 1.0.

E2.1.4 Nonradionuclide Carcinogenic Risk

Hexavalent chromium is the only nonradionuclide carcinogenic COC; the risk value (7.5×10^{-11} in the shallow zone) is well below the individual and cumulative risk limits of 1×10^{-6} and 1×10^{-5}, respectively.

E2.2 PROTECTION OF GROUNDWATER AND THE RIVER

E2.2.1 Radionuclides

The estimated radionuclide dose via the groundwater and/or river pathways is well below the 4 mrem/yr dose rate limit.

E2.2.2 Nonradionuclides

The remaining concentrations of total and hexavalent chromium, mercury, and lead are protective of groundwater and the river.

E3.0 WASTE SITE RECLASSIFICATION

The site meets cleanup standards and has been reclassified as "closed out" in accordance with the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al. 1994) and the Waste Site Reclassification Guideline TPA-MP-14 (RL-TPA-90-0001) (DOE-RL 1990). A copy of the waste site reclassification form is included as Attachment ES-1.

Attachment ES-1

Waste Site Reclassification Form

Date Submitted: 7/19/99 **Originator:** F. M. Corpuz **Phone:** 373-1661	**Operable Unit(s):** 100-BC-1 **Waste Site ID:** 116-B-13 South Sludge Trench (Also known as 107-B) **Type of Reclassification Action:** Rejected ☐ Closed Out ☒ No Action ☐	**Control Number:** 99-034 **Lead Agency:** EPA

This form documents agreement among the parties listed below authorizing classification of the subject unit as rejected, closed out, or no action and authorizing backfill of the site, if appropriate. Final removal from the NPL of no action or closed-out sites will occur at a future date.

Description of current waste site condition:

Remedial action at this site has been performed in accordance with remedial action objectives and goals established by the U.S. Environmental Protection Agency and the Washington State Department of Ecology, in concurrence with the U.S. Department of Energy, Richland Operations Office. The selected remedial action involved (1) excavating the site to the extent required to meet specified soil cleanup levels, (2) disposing of contaminated excavation materials at the Environmental Restoration Disposal Facility at the 200 Area of the Hanford Site, and (3) backfilling the site with clean soil to adjacent grade elevations. The excavation and disposal activities have been completed. The site is currently an open excavation with sloping walls. The exposed surfaces have all been sampled and analyzed. The site will be backfilled in the near future.

Basis for reclassification:

The 116-B-13 South Sludge Trench has been remediated to meet the cleanup standards specified in the *Interim Action Record of Decision for the 100-B/C-1, 100-DR-1, and 100-HR-1 Operable Units* (EPA 1995) and the *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE-RL 1998b). The basis for reclassification is described in detail in the *Cleanup Verification Package for the 116-B-13 South Sludge Trench* (CVP-99-00002).

Glenn I. Goldberg DOE Project Manager	Signature	7/22/99 Date
N/A Ecology Project Manager	Signature	Date
Dennis Faulk EPA Project Manager	Signature	7-22-99 Date

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ACRONYMS

COC	contaminant of concern
DAF	dilution attenuation factor
DQA	data quality assessment
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERC	Environmental Restoration Contractor
ERDF	Environmental Restoration Disposal Facility
GEA	gamma energy analysis
MCL	maximum contaminant level
MTCA	Model Toxics Control Act
MRDS	man-carried radiological data system
NaI	sodium iodide
NGVD29	National Geodetic Vertical Datum 1929
PCB	polychlorinated biphenyl
PQL	practical quantitation limit
QA	quality assurance
QC	quality control
RAG	remedial action goal
RAO	remedial action objective
RCF	Radiological Counting Facility
RDR/RAWP	Remedial Design Report/Remedial Action Work Plan
RESRAD	RESidual RADioactivity Dose Model
RL	U.S. Department of Energy, Richland Operations Office
ROD	Record of Decision
RPD	relative percent difference
SAP	sampling and analysis plan
UCL	upper confidence limit
WAC	Washington Administrative Code

1.0 INTRODUCTION

1.1 PURPOSE

This cleanup verification package documents the attainment of the remedial action objectives (RAOs) and corresponding remedial action goals (RAGs) for the 116-B-13 South Sludge Trench (hereinafter referred to as the 116-B-13 site). Remedial action objectives are narrative statements that define the extent to which the waste sites require cleanup to protect human health and the environment. Remedial action goals are contaminant-specific numerical cleanup criteria developed to ensure that remedial actions will meet the RAOs. Site-specific data evaluations are presented to demonstrate protection from direct exposure and protection of groundwater and surface waters, including the Columbia River.

As shown in Figure 1, the 116-B-13 site is located within the 100-BC-1 Operable Unit in the 100 Areas of the Hanford Site in southeastern Washington State.

1.2 REMEDIATION AUTHORITY

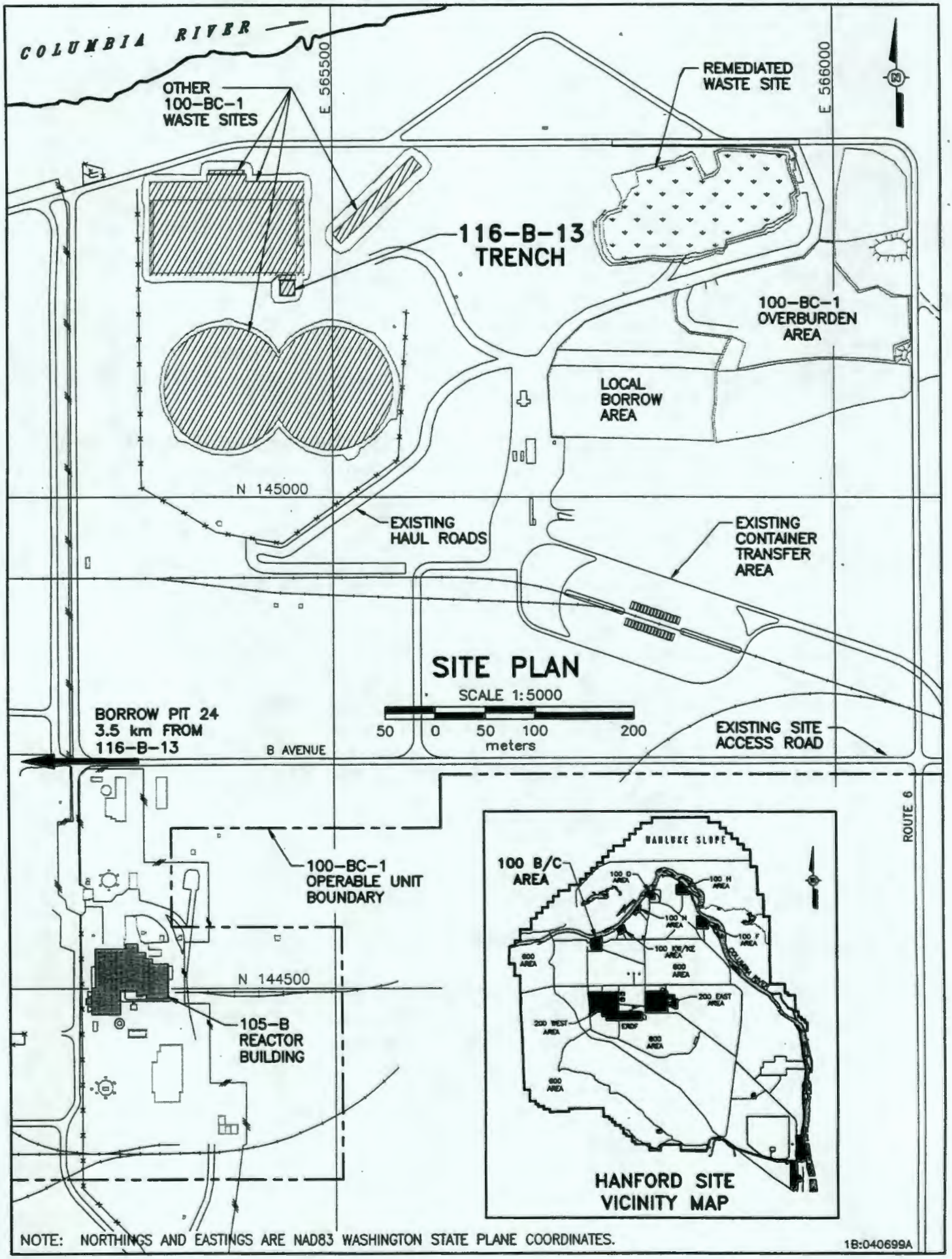
The 116-B-13 site remediation was performed in accordance with an Interim Action Record of Decision (ROD) signed in September 1995 (EPA 1995). The ROD provided the U.S. Department of Energy, Richland Operations Office (RL) the authority and guidelines to conduct this remedial action at the 116-B-13 site. The preferred remedy specified in the ROD was excavation and disposal of contaminated materials at the Environmental Restoration Disposal Facility (ERDF). The RAOs for this site are presented in the ROD (EPA 1995), and the RAGs are discussed in Section 4.0. Methods to attain the RAOs are presented in the *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (RDR/RAWP) (DOE-RL 1998b) and are discussed in further detail in the *100 Area Remedial Action Sampling and Analysis Plan* (SAP) (DOE-RL 1998a) and in other referenced documentation.

1.3 DOCUMENT ORGANIZATION

The cleanup verification evaluation is presented in the following sections:

- Section 2.0 -- Site Description and Supporting Information
- Section 3.0 -- Cleanup Verification Sampling, Analysis, and Data Evaluation
- Section 4.0 -- Remedial Action Goal Evaluation
- Section 5.0 -- Radionuclide Risk Information
- Section 6.0 -- Statement of Protectiveness
- Section 7.0 -- References
- Section 8.0 -- Bibliography.

Figure 1. Hanford Site Map and 116-B-13 Site Plan.



2.0 SITE DESCRIPTION AND SUPPORTING INFORMATION

2.1 SITE HISTORY

The 116-B-13 site, commonly known as the 107-B South Sludge Trench, received radioactive sludge wastes in 1952. This site and the 116-B-14 North Sludge Trench were associated with maintenance cleanout of the 116-B-11 (107-B) Retention Basin, which was constructed in 1944. The 116-B-11 Retention Basin held 100-B Reactor effluent water for a brief time, allowing radioactive decay and thermal cooling to occur before the water was discharged to the Columbia River. The 116-B-13 site is about 220 m (725 ft) from the Columbia River (Figure 1). The sludge pits were built to receive the sludge removed from the bottom of the effluent retention basin, during periodic maintenance of the basin. There is no indication from available records that this sludge pit directly received any regular and/or high-volume liquid effluent wastes. After its use, the waste site was covered with about 1.8 m (6 ft) of soil.

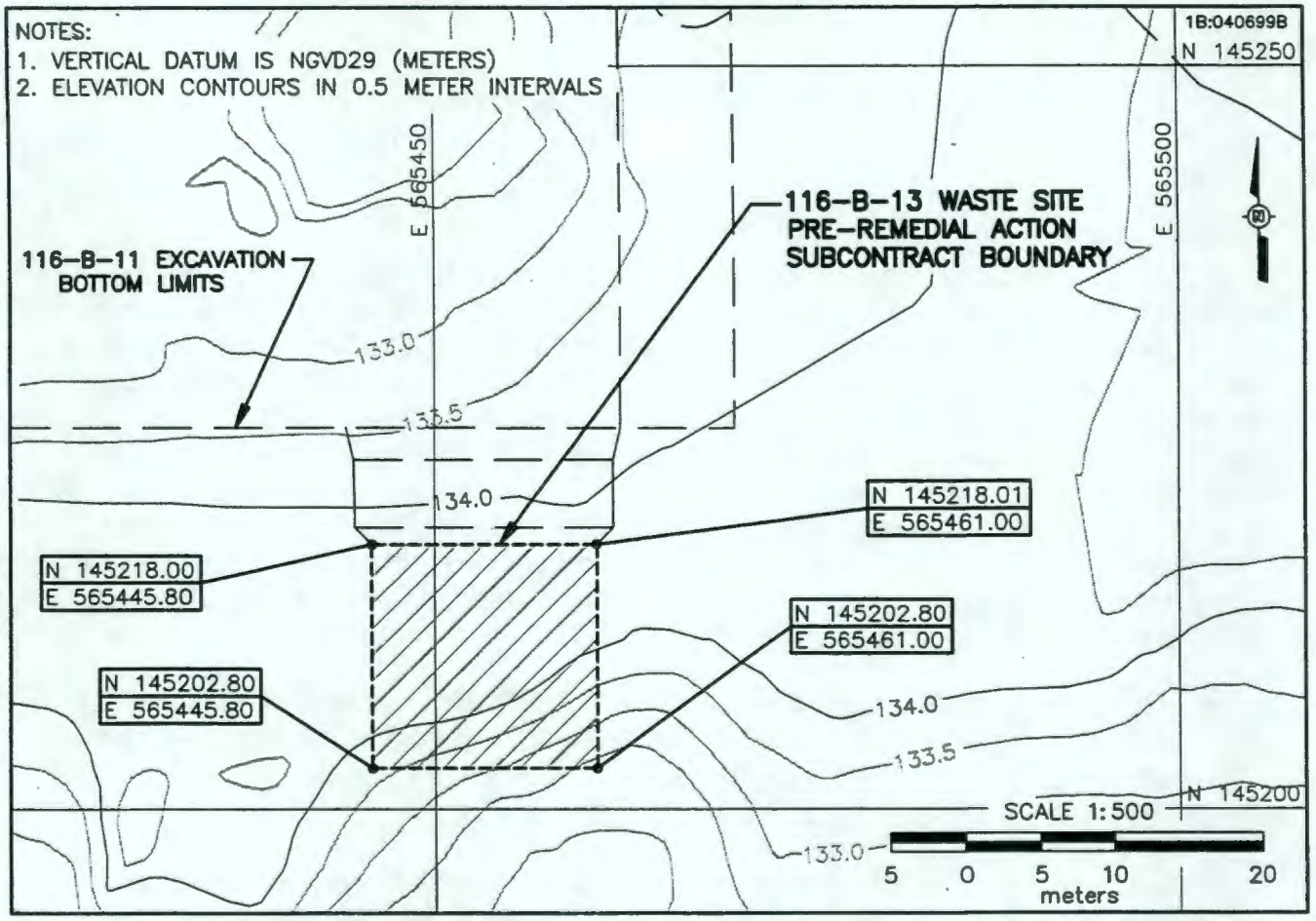
Hanford Site coordinates and elevation contours of the site prior to and after completion of this remedial action are presented in Figure 2. Current adjacent average elevation is approximately 132.5 m (435 ft) above sea level. All elevations presented in this report are in National Geodetic Vertical Datum 1929 (NGVD29).

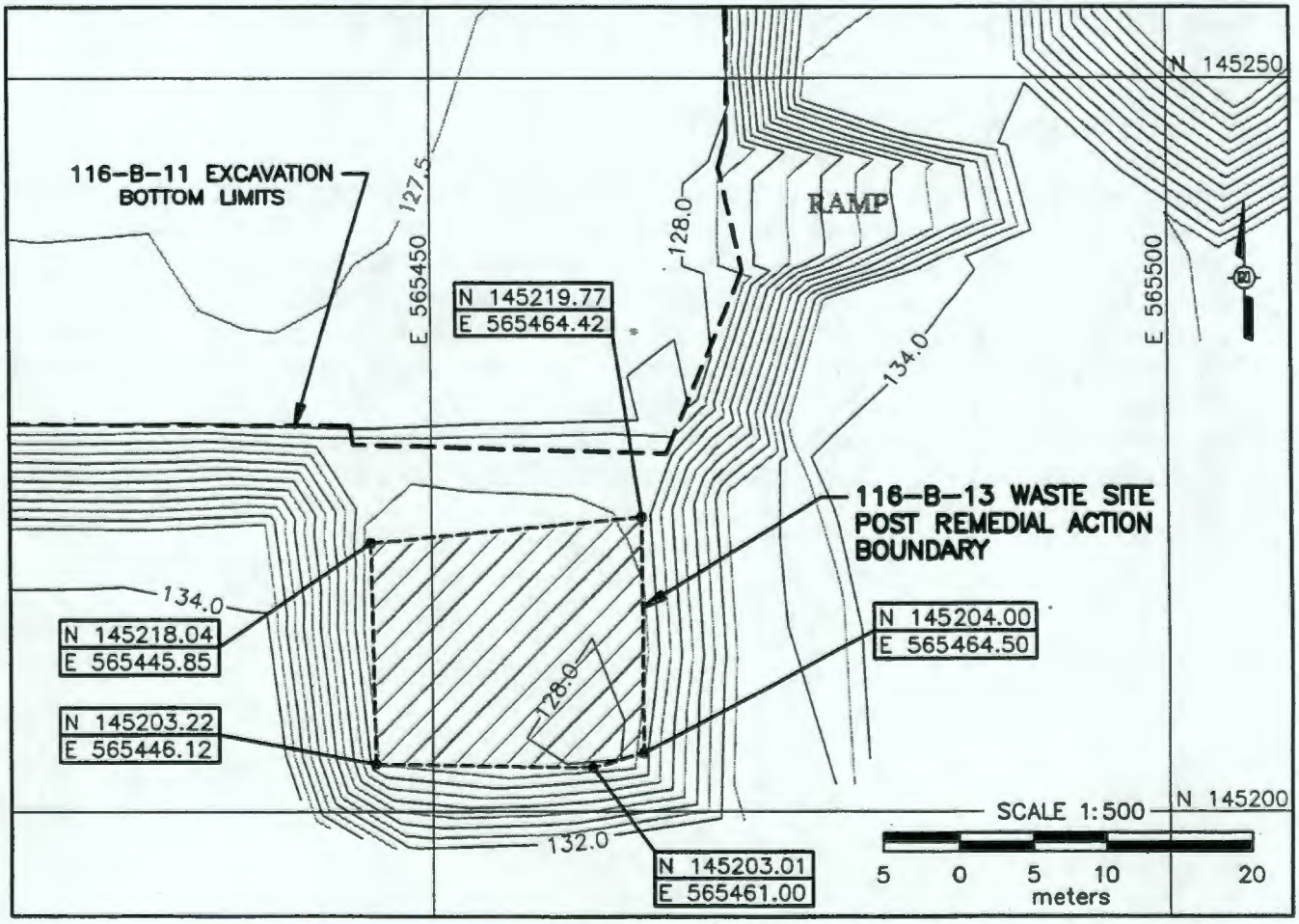
The sludge pit consisted of an approximately 232-m^2 (2,500-ft^2) unlined excavation. This pit extended to a depth of about 3 m (10 ft) below grade and was surrounded by native sandy gravel soils at the base and side walls of the excavation.

2.2 SUBSURFACE CONDITIONS

The soil column underlying the waste site and extending to the groundwater (vadose zone) consists of material from the Hanford formation. The Hanford formation consists predominantly of medium dense to dense sand and gravel, with various degrees of silt and cobble-sized materials. The long-term groundwater level beneath the site is estimated at El. 120.2 m (394 ft) for analysis purposes, based on historical and current information from adjacent groundwater wells. The depth to groundwater beneath the site from the floor of the excavation is estimated to be 8 m (26.2 ft). Current groundwater elevations in adjacent wells are influenced by the nearby Columbia River and other factors that result in periodic groundwater fluctuations.

Figure 2. 116-B-13 Pre- and Post-Remediation Topographic Plans.





2.3 CONTAMINANTS OF CONCERN

From process knowledge, the waste site contaminants of concern (COCs) identified in the SAP include the following (DOE-RL 1998a):

- Americium-241
- Cobalt-60
- Cesium-137
- Europium-152
- Europium-154
- Europium-155
- Plutonium-238
- Plutonium-239/240
- Strontium-90
- Uranium-238
- Total chromium
- Hexavalent chromium (Cr^{+6})
- Mercury
- Lead.

2.4 REMEDIAL ACTION DESCRIPTION

Excavation of the 116-B-13 site began on August 7, 1998, by removing the overburden materials and underlying contaminated soil. Based on field screening, overburden materials that were identified as potentially clean were placed in stockpiles for potential use as backfill. Overburden materials that were found to be contaminated were disposed of at the ERDF. On November 6, 1998, the excavation had reached the design limits at the base of the engineered structure El. 128.2 m (421 ft) and cleanup verification sampling was initiated.

Waste materials that were excavated, loaded into shipping containers, and disposed of at the ERDF consisted of soils not meeting direct exposure RAGs based on field screening results.

At the completion of the remedial action, the excavation footprint area was approximately 620 m^2 (6,674 ft^2) at a depth of 4.3 m (14 ft), and approximately 6,340 metric tons (6,989 tons) of material from the site were disposed of at the ERDF. The excavation will be backfilled in the near future with clean fill materials to the reference grade of El. 132.5 m (435 ft). Clean backfill may be taken from the clean overburden pile and other sources of clean material located near the 116-B-13 site that have been surveyed in accordance with the SAP (DOE-RL 1998a) and that are appropriate for use as backfill.

3.0 CLEANUP VERIFICATION SAMPLING, ANALYSIS, AND DATA EVALUATION

The sampling, analysis, and data evaluation process involves many steps. The primary focus of the efforts is to collect and process the information necessary to verify that the site is clean. A flowchart depicting each step of the sampling, analysis, and data evaluation process is presented in Figure 3. More detailed explanations of the 116-B-13 site efforts are provided in the following sections.

3.1 RADIOLOGICAL FIELD SCREENING

Field screening techniques are used during certain phases to minimize interruptions of the remedial action and to lower analytical costs. Three main gamma radiation (direct exposure) field screening technologies were used at this site: (1) man-carried radiological data system (MRDS) mapping, (2) hand-held sodium iodide (NaI) detectors, and (3) gamma energy analysis (GEA) performed at the Radiological Counting Facility (RCF). Screening technologies, such as hand-held and cart-mounted NaI detectors, were used to guide day-to-day excavation activities and provided >50% coverage of the entire final excavation site.

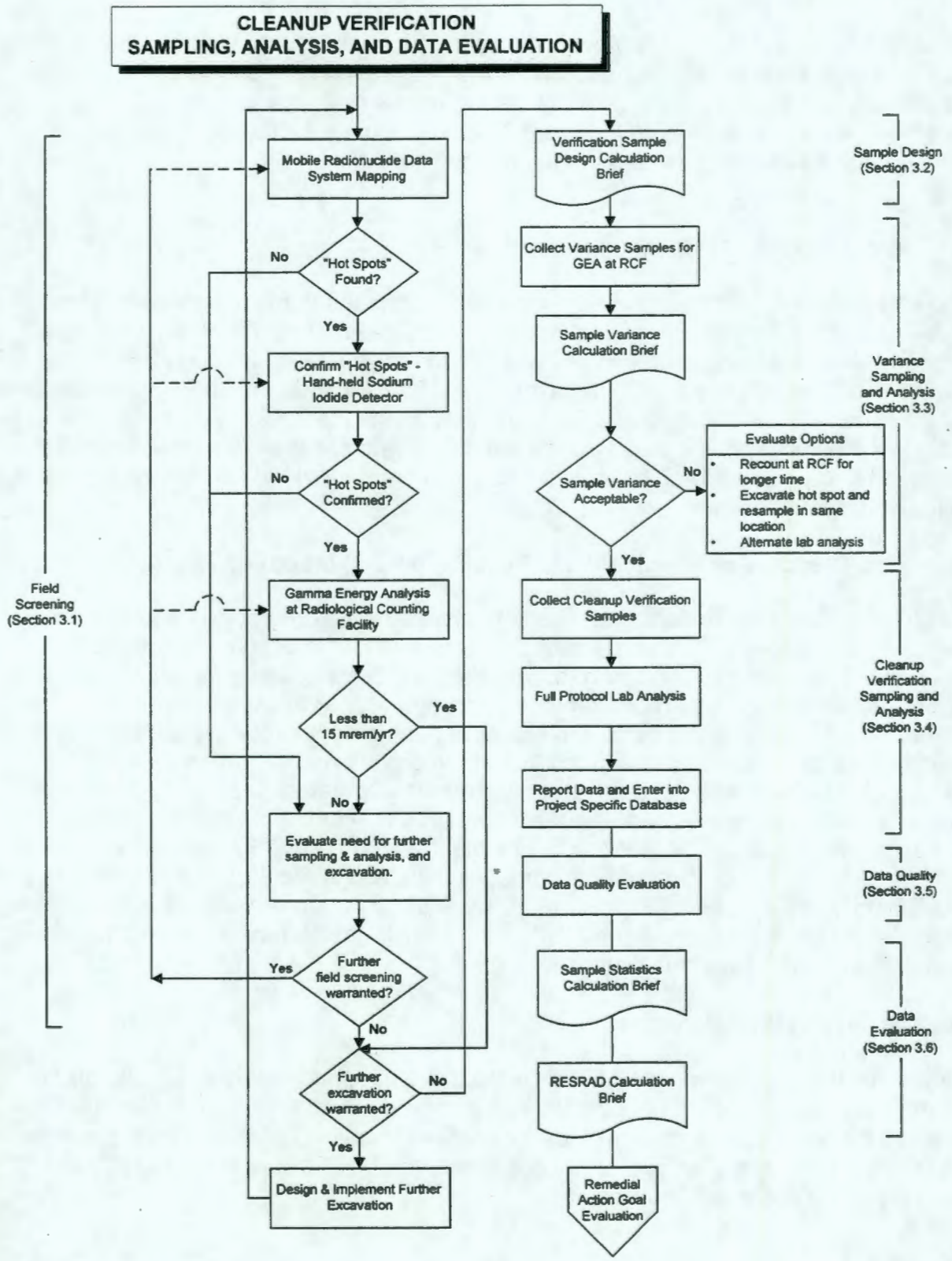
3.1.1 Man-Carried Radiological Data System (MRDS) Mapping

The MRDS technology is deployed when the planned excavation (e.g., subcontract boundary) is completed. This cost- and time-effective tool is used to determine if further excavation is warranted. The NaI gamma energy detector equipment is mounted to a portable cart that is pulled around the site by an operator or backpack mounted. The operator stops at regular intervals and allows the equipment to count radioactivity at that location. Global positioning system coordinate information is transmitted with the radioactivity readings to computers in a nearby van. Operators in the van process the data, and plots of radioactivity at the site are mapped. If hot spots are detected during the MRDS effort, further excavation may be planned. The MRDS surveys were performed over 100% of the site in accordance with field screening procedures (BHI-EE-05, *Field Screening Procedures,* Procedure 2.4, "Operation of the Man-Carried Radiological Detection System [MRDS]"). The MRDS data collection and mapping efforts are documented in the project files.

3.1.2 Sodium Iodide Detector

If hot spots are identified on the MRDS printout of a site map, analysts attempt to confirm the presence of the hot spot with a hand-held NaI detector. If the hot spot is found on the ground, a sample is taken for confirmation via GEA at the RCF (described in Section 3.1.3). If the hot spot is not confirmed, the MRDS survey results at that particular location are reevaluated.

Figure 3. Sampling, Analysis, and Data Evaluation Process Diagram.



3.1.3 Gamma Energy Analysis at the Radiological Counting Facility

During excavation, field screening and onsite GEA at the RCF were used to distinguish between potentially clean materials and contaminated materials for disposal at ERDF. A total of 24 samples were collected for GEA and submitted to the RCF for analysis. Data from these samples were used to corroborate data obtained from field screening, assist in waste characterization, and make variance calculations. Gamma energy analysis is performed at the RCF under controlled conditions. The GEA sampling and analysis efforts are documented in the field logbooks and in the project files.

3.2 SAMPLE DESIGN

In general, a site is thought to be ready for cleanup verification sampling, the sample designs are developed in accordance with the SAP and the field instruction guide (DOE-RL 1998a, BHI 1996). The layout and orientation of the sampling designs are based on the size, shape, and depth of the site.

The sampling designs are used to verify site status after remedial action excavation. Random samples are collected to assess variability in contaminant levels. Each decision unit is separated into several sampling areas. Within each of these sampling areas, a 16-node grid is established and random sampling locations chosen. Based on the variance sample results, samples are then taken from the random points in each sampling area and composited. These composite samples are used to verify that the site was clean.

3.3 VARIANCE SAMPLING AND ANALYSIS

Variance analysis is performed for decision units where direct exposure is a concern. Variance analysis (as described in the SAP, Section A.6 [DOE-RL 1998a]) determines the site-specific number of verification samples. The analysis uses the individual GEA samples and is based on the minimum detectable difference approach presented in U.S. Environmental Protection Agency (EPA) guidance (EPA 1993). In this approach contaminant variability is quantified and used to determine the number of samples required per EPA (1993) to represent the site for clean site verification.

Six variance samples collected from random locations in each of 4 sampling areas (24 samples total) were submitted to the RCF for GEA in accordance with the SAP and the field instruction guide (DOE-RL 1998a, BHI 1996). For the exposed surface of the excavation, initial confirmation sampling and testing using GEA began to determine the number of final verification samples at the base of the engineered structure. The GEA data were used for a preliminary assessment of whether the direct radionuclide exposure RAGs and variance requirements had been met. The GEA indicated a low degree of variability and contaminant levels below the lookup values. The variance analysis is documented in the calculation briefs referenced in Appendix C.

3.4 CLEANUP VERIFICATION SAMPLING AND ANALYSIS

As shown in Figure 4, the shallow zone was divided into four sampling areas for confirmation and verification testing. The required number of samples for the 116-B-13 shallow zone as calculated (see Appendix C) was less than the default number (four composite samples) specified in the SAP (DOE-RL 1998a); therefore, the default number of samples was collected. The base of the excavation is 4.3 m (14.1 ft) below the top of backfill datum elevation and is hence in the "shallow zone" as are the side walls. The "shallow zone" design addresses both shallow and deep zone cleanup criteria.

Four aliquots were collected at prescribed locations (nodes) within the shallow zone areas as described in the calculation briefs (see Appendix C). The four aliquots from each sampling area were composited to create four final cleanup verification samples for the shallow zone soils. The final verification samples were submitted to offsite laboratories for analysis using approved EPA analytical methods, as required per the SAP (DOE-RL 1998a). These results are shown in Appendix A. Verification sampling and testing were finished on November 23, 1998. Sample splits were also taken and analyzed by the EPA; the relevant results are presented in Appendix A as information only.

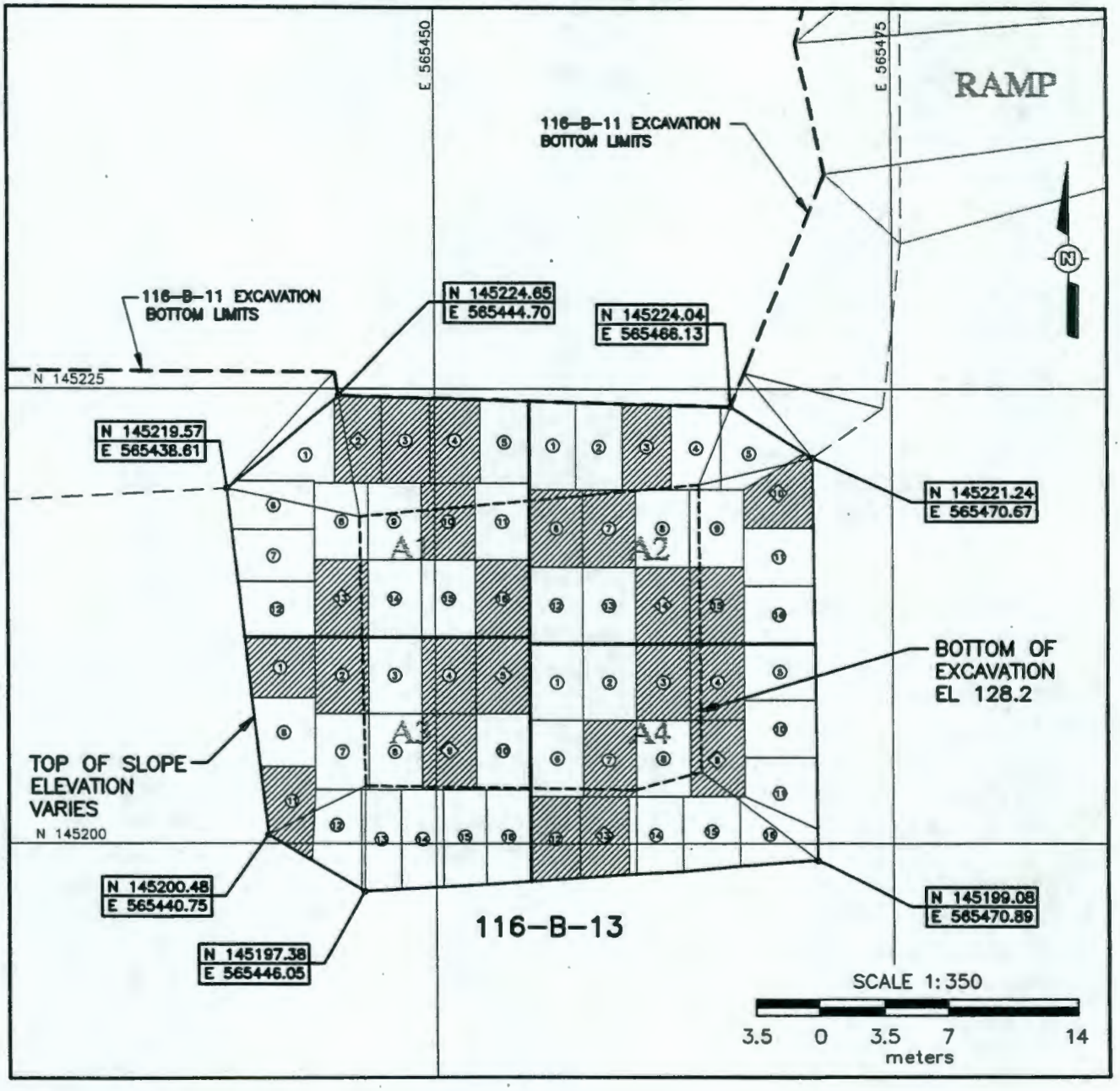
3.5 DATA QUALITY

3.5.1 Field Quality Assurance/Quality Control

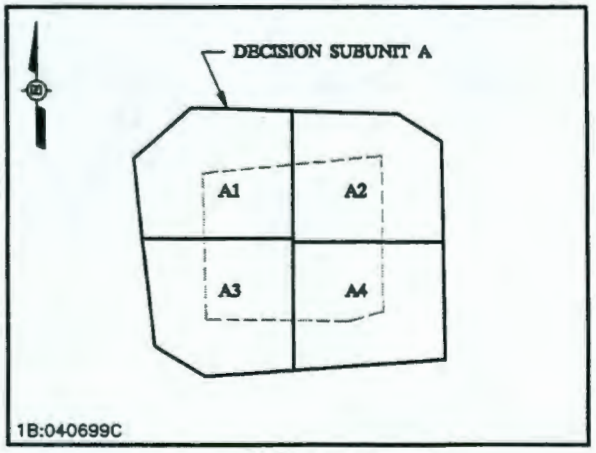
Field quality assurance (QA)/quality control (QC) measures were used to assess potential sources of error and cross-contamination of soil samples that bias results. The QA/QC samples results are used to assess analytical precision and accuracy. The QA/QC samples for this project included two field duplicate samples, an equipment blank sample, and one split sample. All main and QA/QC sample results are presented in Appendix A.

The split sample was analyzed and the results were compared to determine the usability of the verification data. The EPA Contract Laboratory Program duplicate sample comparison methodology, *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (EPA 1994), was used as an initial test of the data from the split. The field main and split samples were evaluated by computing the relative percent difference (RPD) of the split samples for each COC. Only the analytes that had values five times above the detection limits for both the master and duplicate samples were compared. The split laboratory was unable to achieve hexavalent chromium detection levels below the required target detection limit.

Figure 4. 116-B-13 Shallow Zone Sampling Areas, Nodes, and Locations for Cleanup Verification Sampling.



Shallow Zone Sampling Area Locations



NOTES:
1. SHALLOW ZONE SAMPLING NODES APPROXIMATELY 12.36 SQUARE METERS.
2. SAMPLES TAKEN FROM APPROXIMATE CENTER OF EACH NODE.
3. DECISION SUBUNIT A TOTAL AREA: 791.0 SQUARE METERS.

LEGEND

(8)	CLOSEOUT VERIFICATION SAMPLING NODE
(8)	GAMMA ENERGY ANALYSIS SAMPLING NODE

This has no impact on the data, as hexavalent chromium was not detected in any of the samples. The RPD of results for B0T0B5 and the split B0T0R9 were within the +35% range, except for uranium-238 (below 35%) and lead (-128.4%). Because the uranium values are below background levels and the total chromium values are below cleanup levels, this is not a concern. The lead values for both samples are well within the limits of natural background for the Hanford Site (DOE-RL 1996b).

The results for the EPA split samples are also presented in Table A-1. The RPD calculations for the EPA splits showed that all analytes were in the ±35% range.

3.5.2 Data Quality Assessment

A data quality assessment (DQA) is a comparison of the implemented sampling approach and resulting analytical data with the sampling and data quality requirements specified by the project objectives and performance specifications.

The results of a DQA will determine whether the data are of adequate quality and quantity to support the decision-making process. A DQA was performed on the verification sampling results as documented in BHI (1999). Results of the DQA indicated that the number and quality of samples taken for final verification were adequate for final cleanup verification.

A DQA was also performed to ensure that the data were suitable for decision-making purposes. The analytical data were evaluated for compliance with quality assurance project plan requirements (DOE-RL 1998a), including requirements for precision, accuracy, completeness, and method detection limits. The DQA confirmed that all analytical data were acceptable for decision making. The appropriate statistical test was performed on the adjusted raw analytical data (see Appendix B) to determine statistical values for each contaminant. The statistical values supported clean site verification decisions within the specified error tolerances. The number of samples collected for cleanup verification was evaluated to confirm assumptions concerning contaminant variability. The DQA verified that the sample design was sufficient for the purpose of clean site verification and that the laboratory testing results used for final verification were appropriate for site cleanup purposes.

Additional quality requirements of the quality assurance project plan included data acquisition requirements. All verification data are stored in the Hanford Environmental Information System.

All verification samples are subject to laboratory-specific QA requirements, including instrument procurement, maintenance, calibration, and operation. Additional laboratory requirements for internal QC checks are performed as appropriate for the analytical method at a rate of one per sample delivery group, or 1 in 20, whichever is more frequent.

Laboratory internal QC checks include the following:

- Matrix-spike duplicates. Matrix-spiked samples require the addition of a known quantity of a representative analyte of interest to the sample as a measure of recovery percentage and as a test of analytical precision.

- Replicate samples. Replicate samples are separate aliquots removed for the same sample container in the laboratory. Replicate samples are a measure of analytical precision.

- QC reference samples. A QC reference sample is prepared from an independent standard at a concentration other than that used for calibration, but within the calibration range. Reference samples are required as an independent check on analytical technique and methodology.

Verification sample laboratories are also subject to periodic and random assessments of the laboratory performance, system, and overall program. These assessments are performed by the Bechtel Hanford, Inc. Quality Assurance group to ensure that the laboratories are performing to laboratory contract requirements.

3.5.3 Data Validation

After sampling was completed, all of the fixed-base laboratory data were validated to Level C per BHI-EE-01, *Environmental Investigations Procedures*, EIP 2.5, "Data Package Validation Process." Level C validation procedures are specified in WHC (1992a) and WHC (1992b).

Under the Level C validation procedure, the following items were reviewed, as appropriate, for each analytical method:

- Sample holding times
- Method blanks
- Matrix spike recovery
- Surrogate recovery
- Matrix spike/matrix spike duplicate results
- Sample replicates
- Associated batch laboratory control sample results
- Data package completeness.

Data flagged as estimated (i.e., "J") indicate that the associated concentration is an estimate but that the data may be used for decision-making purposes. Data flagged as below detection limits (i.e., "U") indicate that the associated concentration is an estimate but that the data may be used for decision-making purposes. This situation is applicable for sample results that are below detection limits. All other validated results are considered to be accurate within the standard errors associated with the methods.

3.5.3.1 Radiochemistry (Gamma Energy Analysis, Total Radioactive Strontium, Plutonium Isotopic). No major deficiencies were noted for gamma, total radioactive strontium, or plutonium (isotopic) during analyses of the 116-B-13 site.

3.5.3.2 Nonradionuclides (EPA Method 7196). No major deficiencies were noted for the nonradionuclide analyses for the 116-B-13 site. Minor deficiencies were noted in the DQA, resulting in some samples flagged "J." These minor deficiencies still allow the data to be used for decision-making purposes.

3.6 CLEANUP VERIFICATION DATA EVALUATION

Upon completion of the remedial action excavation, cleanup verification samples were taken and analyzed to verify attainment of the established RAOs and corresponding RAGs. The verification sampling, laboratory testing, subsequent analysis, and statistical treatment of the data were performed in accordance with the procedures outlined in the RDR/RAWP and SAP (DOE-RL 1998a, 1998b), field instruction guide (BHI 1996), and in EPA/Washington State Department of Ecology (Ecology) meeting minutes. The resulting engineering and environmental analyses are presented in detail in the calculation briefs identified in Appendix C. The cleanup verification sample results are presented in Appendix A and Section 4.0.

Before the RAOs and corresponding RAGs were evaluated, the following steps were taken to compile and organize the data for the 116-B-13 site:

1. Developed contaminant-specific summary statistics for the excavation site samples

2. Developed a site-specific verification model

3. Prepared a single cleanup verification data set for use in evaluating the attainment of RAGs

4. Performed RESidual RADioactivity Dose Model (RESRAD) modeling.

3.6.1 Statistical Calculation

3.6.1.1 Radionuclides. The primary statistical calculation for radionuclides was the single-tailed 95% upper confidence limit (UCL) on the arithmetic mean of the data. For data qualified with a "U" (i.e., less than detection), the minimum detectable activity was used in the calculation of the 95% UCL. The methodology for this calculation is described in Appendix B.

3.6.1.2 Nonradionuclides. Prior to calculation of the sample statistics, the nonradionuclide data below detection limit were adjusted to one-half the detection limit value, as required by Ecology guidance (Ecology 1993, WAC 173-340). The single-

tailed 95% UCL on the arithmetic mean was then calculated for each COC. The methodology for this calculation is described in Appendix B.

3.6.1.3 Statistical Values. Statistical values represent the COC concentrations for the decision unit (i.e., shallow zone). Statistical values are established in the *116-B-13 95% UCL Calculations for Compliance with Cleanup Standards* (0100B-CA-V0056, see Appendix C) where the data are evaluated per MTCA guidance. Background concentrations of uranium-238 in shallow soils are subtracted from the statistical values. The statistical values are then used in the RESRAD modeling or nonradionuclide risk calculations to evaluate if the RAOs and RAGs have been attained. The verification sampling statistical values for 116-B-13 (side walls and floor) are presented in Table 1.

Table 1. 116-B-13 Verification Sampling Summary Statistics (concentrations used for RESRAD calculations).

Radionuclides (pCi/g)	Shallow Zone Statistical Value Above Background (pCi/g)
Am-241	0.419
Co-60	0.042
Cs-137	0.066
Eu-152	0.098
Eu-154	0.118
Eu-155	0.066
Pu-238	0.032
Pu-239/240	0.036
Sr-90	0.308
U-238	0 (<background)
Nonradionuclides (mg/kg)	**Shallow Zone Statistical Value (mg/kg)**
Total Cr	5.0
Cr^{+6}	0.03
Mercury	0.02
Lead	2.0

Refer to Appendix C for additional details on determining statistical values.

3.6.2 116-B-13 Site-Specific Cleanup Verification Model

3.6.2.1 Shallow Zone. The shallow zone is typically defined as soil from grade level to 4.6 m (15 ft) below the ground surface. The 116-B-13 site excavation extended to a depth of 4.3 m (14.1 ft). Thus, the entire excavation was in the shallow zone. For the purposes of the verification model, the conservative assumption was made that the level of contaminants found during sampling extended from grade level ground surface to groundwater. The model is made even more conservative because the clean backfill material has not been considered in the calculations and no liquid waste was disposed at the site.

3.6.3 Concentrations Above Background

Background concentrations are normally subtracted from the uranium-238 statistical value. The uranium-238 statistical value was less than the Hanford Site background (1.1 pCi/g) and thus not included in the calculations. The background concentrations of nonradionuclide contaminants were not subtracted. Where nonradionuclide statistical values were below background, they were not considered further in the verification analysis.

3.6.4 RESRAD Modeling

The RESRAD (ANL 1998) computer code, Version 5.82, was used to model the impact of residual COC concentrations on the vadose zone, groundwater, and the river. The RESRAD model is intended primarily for radionuclide contaminants. However, the system can also be used for nonradionuclides. The RESRAD modeling results are discussed in Section 4.0. Overviews of the model runs are provided below.

3.6.4.1 Shallow Zone Dose and Risk Evaluation. The cleanup verification values (Table 1) and site-specific parameters were entered into RESRAD for analysis of (1) total radionuclide dose (effective dose mrem/yr) and (2) estimated risk attributable to radionuclides.

To meet the RAGs described in Section 4.2, the RESRAD model used several conservative assumptions, such as the following:

- Th excavation is backfilled with soil contaminated at the same level as the excavation side slopes, instead of clean material.

- The residents at the site are living in contact with these contaminated soils and are not protected by a concrete basement or clean fill under the basement.

The RESRAD input parameters are provided in Appendix C. The analysis is documented in calculation brief 0100B-CA-N0009, which is referenced in Appendix C.

3.6.4.2 Protection of Groundwater Evaluation. The cleanup verification statistical values (radionuclide and one nonradionuclide COCs) and site-specific parameters were

entered into RESRAD for analysis of individual COC groundwater concentrations from residual COC concentrations in soil. The results were then compared against maximum contaminant levels (MCLs) and "National Primary Drinking Water Regulations" (40 CFR 141) requirements. A description of this methodology is found in Section 4.4.1.

The RESRAD input parameters are provided in Appendix C. The analyses are documented in calculation brief 0100B-CA-N0009 (see coversheet and summary in Appendix C).

4.0 REMEDIAL ACTION GOAL EVALUATION

4.1 REMEDIAL ACTION OBJECTIVES

Remedial action objectives are broad guidelines intended to define and guide the remediation work. The RAOs are presented in the 100 Areas ROD (EPA 1995). A brief summary of the RAOs is presented below. For more detailed information on the RAOs, see the RDR/RAWP (DOE-RL 1998b) and the ROD (EPA 1995).

1. Protection from direct exposure. Protect human and ecological receptors from exposure to contaminants in soils, structures, and debris by dermal exposure, inhalation, or ingestion of radionuclides, inorganics, or organics.

2. Groundwater and river protection. Control the sources of groundwater contamination to minimize the impacts to groundwater resources, protect the Columbia River from further adverse impacts, and reduce the degree of groundwater cleanup that may be required under future actions.

3. Unlimited future land use. To the extent practicable, return soil concentrations to levels that allow for unlimited future use and exposure. Where it is not practicable to remediate to levels that will allow for unrestricted use in all areas, institutional controls and long-term monitoring will be required.

4.2 REMEDIAL ACTION GOALS

Remedial action goals are the specific numeric goals applied to evaluate the attainment of the RAO. Future land use of the 100 Areas is not yet defined; therefore, the RAGs have been developed to support a rural residential exposure scenario. The rural residential scenario includes the following:

- Individual living in a house with a 3.7-m (12-ft)-deep basement.
- The individual spends 25% of his/her lifetime in the basement.
- The home is located directly on top of the remediated site.
- Locally raised livestock or game animals are consumed.
- Groundwater is used for irrigation, drinking water, household use, and livestock.
- Fish are consumed from the nearby body of water.
- Individual ingests 36.5 g/yr of residual soil.

The relevant pathways are:

- External gamma
- Inhalation
- Plant ingestion
- Meat ingestion

- Milk ingestion
- Aquatic foods ingestion
- Drinking water ingestion
- Soil ingestion.

A more detailed description of the rural residential scenario and how it is applied is provided in the RDR/RAWP (DOE-RL 1998b).

The second RAO is addressed by evaluating the radionuclide COCs with the RESRAD model for compliance with the "National Drinking Water Regulations," and for nonradionuclides by meeting RAGs based on MCLs.

The third RAO is addressed via the assessment of the first two RAOs (and corresponding RAGs) under a rural residential exposure scenario. No further RAGs are defined to address the third RAO.

The RAGs and the RAG evaluations presented in this report are consistent with the RDR/RAWP (DOE-RL 1998b), the SAP (DOE-RL 1998a), and subsequent agreements between EPA, Ecology, and RL in December 1997. These agreements are included in the Administrative Record and will be included in the next revision of the RDR/RAWP.

4.2.1 Remedial Action Goal Overview

The RAGs that were applicable to this verification package are defined in the RDR/RAWP (DOE-RL 1998b).

Direct exposure: For soils in the shallow zone (<4.6-m [15-ft] depth) or retained overburden used as backfill:

- For radionuclide COCs, meet a 15 mrem/yr above background total dose rate (this RAG must be met for 1,000 years).

- For nonradionuclide COCs:

  - Meet soil concentration RAGs.

  - Attain a hazard index of less than 1 for noncarcinogenic contaminants.

  - Attain an excess cancer risk of less than 1×10^{-6} for individual carcinogenic contaminants.

  - Attain a cumulative excess cancer risk of less than 1×10^{-5}.

Protection of groundwater: For residual COC concentrations in vadose zone soils under an irrigation scenario of 76 cm/yr (30 in./yr) for 1,000 years:

- For beta- and gamma-emitting radionuclide COCs, meet "National Primary Drinking Water Regulations" dose standards (4 mrem/yr total body organ dose) for a period of 1,000 years starting from site cleanup verification. Meet individual COC RAGs as applicable (e.g., strontium-90).

- For nonradionuclide COCs, meet individual COC soil RAGs.

Protection of surface waters (including the Columbia River): For residual COC concentrations in vadose zone soils, under an irrigation scenario of 76 cm/yr (30 in./yr) for 1,000 years:

- For radionuclide COCs, meet "National Primary Drinking Water Regulations" dose standards (4 mrem/yr) for a period of 1,000 years starting from site cleanup verification. Meet individual COC RAGs as applicable (e.g., strontium-90).

- For nonradionuclide COCs, meet individual COC soil RAGs.

4.2.2 Specific Remedial Action Goals

The RAGs are presented in Table 2. Radionuclide RAGs are discussed further in Section 4.2.2.1, and nonradionuclide RAGs are discussed further in Section 4.2.2.2.

Table 2. Summary of Remedial Action Goals. (2 pages)

COCs	Direct Exposure RAG	Groundwater Protection RAG[b] (pCi/L)	Columbia River Protection RAG[b] (pCi/L)
Radionuclides			
Am-241	15 mrem/yr (cumulative)[a]	1.2	1.2
Co-60		147	147
Cs-137		120	120
Eu-152		235	235
Eu-154		59	59
Eu-155		587	587
Pu-238		1.6	1.6
Pu-239/240		1.2	1.2
Sr-90		8[c]	8[c]
U-238		24	24
Cumulative groundwater and river protection		"National Primary Drinking Water Regulations	"National Primary Drinking Water Regulations"

Table 2. Summary of Remedial Action Goals. (2 pages)

COCs	Direct Exposure RAGs (mg/kg)	Groundwater Protection		Columbia River Protection		
		Action Levels (µg/L)	Soil RAG (mg/kg)	Action Levels (µg/L)	Near River Action Levels (µg/L)	Soil RAG (mg/kg)
Nonradionuclides						
Total chromium	80,000	16,000	1,600[d]	180	360	36[e]
Hexavalent chromium	400	80	8[d]	11	22	2.2[e]
Mercury	24	2	0.33[f]	0.012	0.024	0.33[f]
Lead	353[g]	15	10.2[f]	1.78	3.56	10.2[f]

[a] Lookup values that correspond to the 15 mrem/yr dose rate and a generic site model are presented in the *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (RDR/RAWP) (DOE-RL 1998b).
[b] Lookup value, individual radionuclide 4 mrem/yr dose equivalent.
[c] Promulgated groundwater protection standard.
[d] Soil RAG based on "100 times MCL" rule.
[e] Soil RAG based on "100 times MCL times DAF" rule.
[f] The "100 times MCL" and "100 times MCL times DAF" soil values were less than Hanford Site soil background concentrations; therefore, background values are used as the soil RAG.
[g] Derived from the Integrated Exposure Uptake Biokinetic (IEUBK) Model for lead in children (EPA 1994a).
COC = contaminant of concern
RAG = remedial action goal

4.2.2.1 Radionuclide RAGs. The direct exposure radionuclide RAG is 15 mrem/yr. The attainment of this RAG was demonstrated via RESRAD modeling.

The protection of groundwater and the Columbia River is determined by attainment of nuclide-specific RAGs and attainment of "National Primary Drinking Water Regulations" criteria (Section 4.4.1) for determining the cumulative impact of radionuclides. The RESRAD model calculates the individual COC concentrations in groundwater that would result from the residual soils under a 76-cm/yr (30-in./yr) irrigation scenario for 1,000 years. These individual concentrations are directly compared to the RAGs. The individual concentrations are also used in calculations to determine if the cumulative dose exceeds "National Primary Drinking Water Regulations" standards.

4.2.2.2 Nonradionuclide RAGs. The nonradionuclide direct exposure, protection of groundwater, and protection of river RAGs are summarized in Table 2.

The protection of groundwater and river RAGs can be derived by two methods: (1) the "100 times MCL" rule for groundwater, or the "100 times MCL times dilution/attenuation factor (DAF)" rule for the river; or (2) RESRAD modeling. If the RAGs developed under the first method are below Hanford Site background values or the practical quantitation limit, the background value or practical quantitation limit (whichever is greatest) will be used as the RAG.

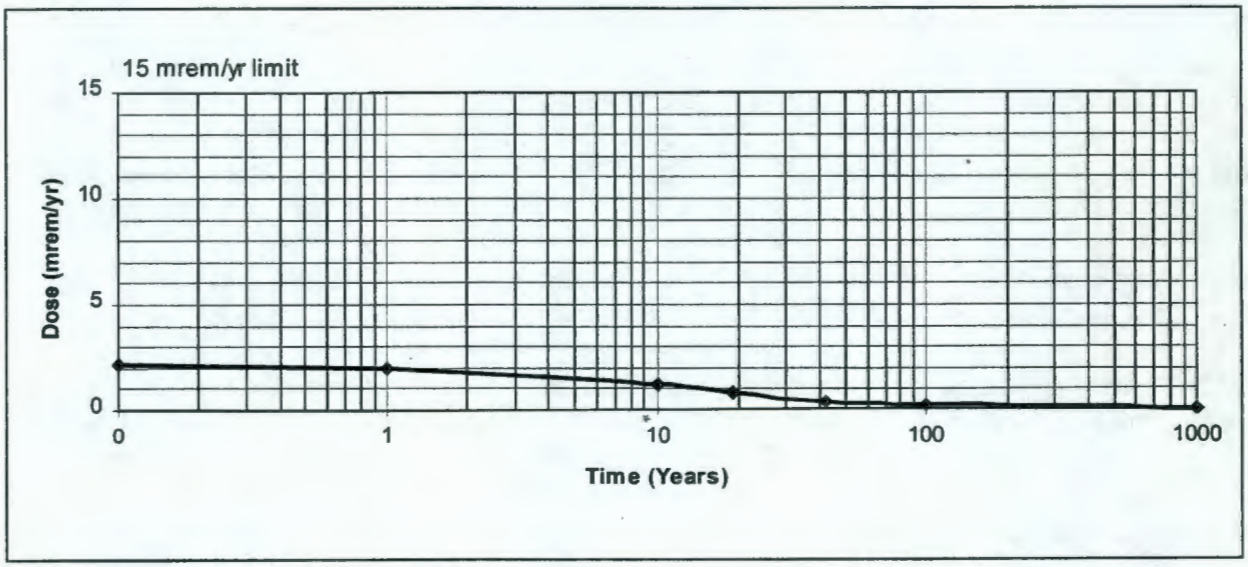
If the statistical cleanup verification value is higher than the RAGs developed under Method 1, groundwater and river protection are evaluated using RESRAD modeling and by considering the travel time to the river.

4.3 ATTAINMENT OF DIRECT EXPOSURE SOIL CLEANUP STANDARDS

4.3.1 Radionuclide Direct Exposure Standards

The RESRAD computer code (ANL 1998) was used to demonstrate that the direct exposure radionuclide dose limit of 15 mrem/yr is not exceeded. The individual radionuclide cleanup verification data (Table 1) were entered into the RESRAD model for evaluation (the RESRAD model setup and input parameters are provided in Appendix C). The results of the RESRAD dose estimate under the all-pathways scenario are presented in Figure 5. This dose represents the summed dose contributions from soils at the relevant time slices. The total dose is largest at present, 2.40 mrem/yr, and decreases to 0.03 mrem/yr in 1,000 years. The total dose rate in 19 years (the year 2018) is estimated to be 1.12 mrem/yr. The actual doses at the waste site will be considerably less than these calculations because (1) the site-specific model conservatively assumes soil contamination continues uniformly to groundwater, and (2) the site will be backfilled with 4.3 m (14.10 ft) of clean backfill. This computation is presented in detail in the referenced calculation briefs, summarized in Appendix C.

Figure 5. RESRAD Analysis – All Radionuclides, All Pathways, Shallow Zone Dose Estimate.



4.3.2 Attainment of Nonradionuclide Direct Exposure Cleanup Standards

4.3.2.1 Attainment of Remedial Action Goals. A direct comparison of the RAGs in Table 2 and the cleanup verification values in Table 1 indicates that the RAOs for nonradionuclide COCs have been attained. This comparison is summarized for shallow zone soils in Table 3.

Table 3. Attainment of Nonradionuclide Cleanup Standards for Soil.

Nonradionuclides (mg/kg)	RAG (mg/kg)	Statistical Value (mg/kg)[a]	Maximum Detected (mg/kg)[b]	Total Number of Samples	Number of Samples that Exceed Criteria[c]	RAGs Attained?
Shallow Zone						
Total chromium	80,000	5.0	5.7	4	0	Yes
Hexavalent chromium	2.2[d]	0.03	0.03	4	0	Yes
Mercury	24	0.02	0.02	4	0	Yes
Lead	353	2.0	2.3	4	0	Yes

[a] Criterion is comparison to the cleanup criteria (RAG).
[b] Criterion is no single detection can exceed two times the cleanup criteria.
[c] Criterion is no more than 10% of the samples can exceed the cleanup criteria.
[d] This value is based on river protection and is not a MTCA human risk-based number.

4.3.2.2 Attainment of Noncarcinogenic Risk Standards. For noncarcinogenic COCs, the *Model Toxics Control Act* (MTCA) specifies the evaluation of the hazard quotient, which is given as daily intake divided by a reference dose (DOE-RL 1995). For cleanup actions under the interim action ROD (EPA 1995), a comparable conservative approach is used to demonstrate attainment of the noncarcinogenic risk requirements.

The nonradionuclide chemical cleanup levels for soil are based on the MTCA Method B limits. These cleanup limits were set to be compliant with a hazard quotient of 1.0; therefore, the ratio of the cleanup verification values to the cleanup limits (lookup value obtained from the RDR/RAWP [DOE-RL 1998b]) provides a conservative evaluation of the individual hazard quotients. For multiple COCs, the sum of the ratios of each COC statistical value to the cleanup limit is used to evaluate an overall hazard quotient.

For this site, the sum of the ratios for the noncarcinogenic COC (0.0066 in soils) is less than a hazard index of 1, demonstrating that the RAOs have been attained.

4.3.2.3 Attainment of Carcinogenic Risk Standards. For individual carcinogenic COCs, the MTCA Method B cleanup limits are based on an incremental cancer risk of 1×10^{-6}. Per agreement between RL, Ecology, and EPA, the ratio of the statistical value from the verification samples divided by the risk limit is used to provide an estimate of the risk associated with the statistical value. As was noted in Section 4.3.2.2, the cleanup limits are based on MTCA Method B limits or more stringent limits (depending on the groundwater or river protection requirements). The calculation methodology for deriving carcinogenic risk is presented in Appendix B.

Hexavalent chromium is the only nonradionuclide carcinogen at the 116-B-13 site. Hexavalent chromium has both carcinogenic and noncarcinogenic toxicity characteristics. For the shallow zone, the individual COC and cumulative risk values calculated in this manner is 7.50×10^{-11}, well below the individual and cumulative risk limits of 1×10^{-6} and 1×10^{-5}, respectively. This calculation was performed and documented in a calculation brief (0100B-CA-V0056, Rev. 0) summarized in Appendix C.

4.4 ATTAINMENT OF GROUNDWATER REMEDIAL ACTION GOALS

4.4.1 Radionuclides

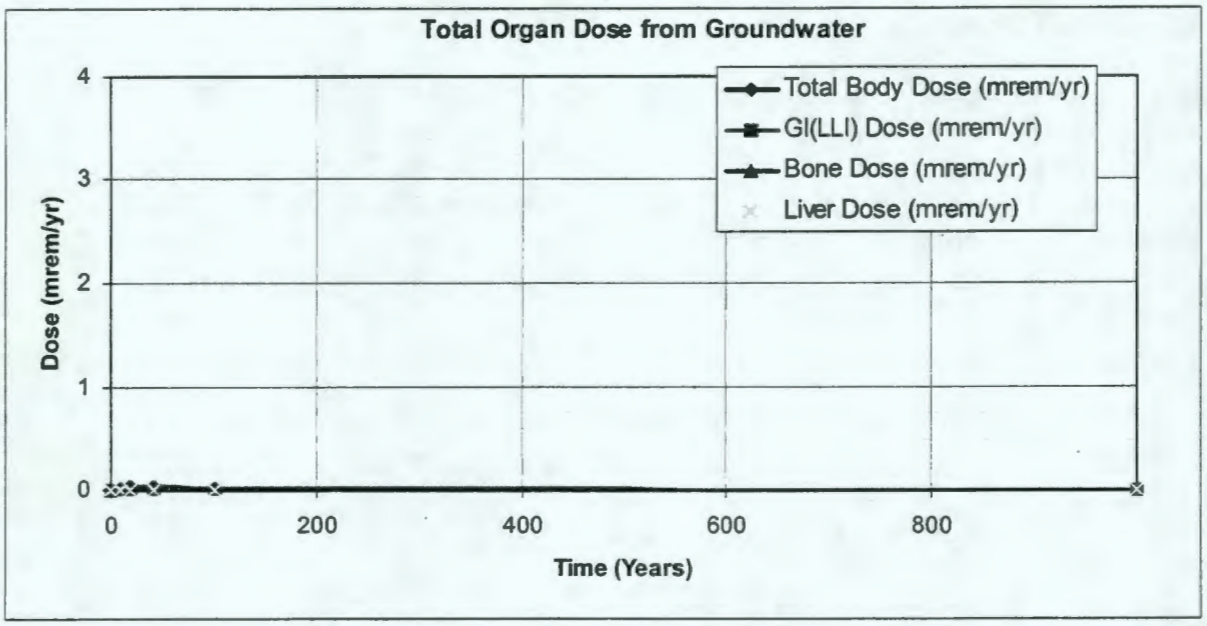
Table 4 shows the total peak concentration for each COC as calculated by RESRAD and provides the individual RAGs for comparison. The model used the conservative approach that the levels of COCs detected during verification sampling extended to groundwater. No COC exceeded the RAGs. Since the alpha emitters (americium-241, plutonium-238, plutonium-239/240) do not reach groundwater within 1,000 years, they meet the 15 pCi/L standard. Details of the RESRAD calculations are shown in Appendices B and C.

Table 4. Estimated Peak Radionuclide Groundwater Concentrations Compared to RAGs.

Radionuclide	Peak Concentration (pCi/L)	Time of Peak Concentration (Years)	RAG (pCi/g)
Am-241	0	0	1.2
Co-60	0.0001173	10	147
Cs-137	0.002984	42	120
Eu-152	0	0	235
Eu-154	0	0	59
Eu-155	0	0	587
Pu-238	0	0	1.6
Pu-239/240	0	0	1.2
Sr-90	0.1176	42	8

The "National Primary Drinking Water Regulations" (40 CFR 141) establish a 4-mrem/yr dose standard for beta- and gamma-emitting radionuclides in drinking water. They also specify the method of calculating dose: the individual organ-dose calculational method given in NBS Handbook 69 (NBS 1963). The radionuclide COCs that are beta or gamma emitters are cobalt-60, cesium-137, europium-152, europium-154, europium-155, and strontium-90. Figure 6 shows the individual organ doses over 1,000 years for gastrointestinal tract-lower large intestine [GI(LLI)], bone, liver, and total body. None of the organ doses exceeded the 4 mrem/yr standard over 1,000 years.

Figure 6. 116-B-13 Dose to Organs from Groundwater.



4.4.2 Nonradionuclides

The methodology demonstrating the attainment of the RAGs for nonradionuclides is summarized in Appendix B and in EPA/Ecology/RL meeting minutes (EPA et al. 1998, Ecology 1997). Site-specific calculations are presented in the calculation briefs found in Appendix C, Section C2. The total and hexavalent chromium, lead, and mercury statistical values are below the protection of groundwater RAGs of 1,600 mg/kg, 8 mg/kg, 10.2 mg/kg, and 0.33 mg/kg, respectively and, therefore, meet the groundwater protection RAG for the entire 1,000-year time frame evaluated.

4.5 ATTAINMENT OF COLUMBIA RIVER REMEDIAL ACTION GOALS

4.5.1 Radionuclides

The river protection RAGs for radionuclides are identical to the groundwater protection RAGs. The RESRAD model was used to calculate the cumulative dose effect and the individual radionuclide concentration in groundwater that would result from the residual COC concentrations in 116-B-13 site soils under a 76 cm/yr (30 in./yr) scenario for 1,000 years. These values were then compared to the groundwater protection RAGs listed in Table 2.

The RESRAD modeling results indicated that radionuclides do not reach groundwater (and by extension, do not reach the Columbia River) at levels above the 4 mrem/yr RAG. In addition, the individual COCs do not result in groundwater or river concentrations at levels above the individual COC RAGs; therefore, the protection of river RAGs have been attained.

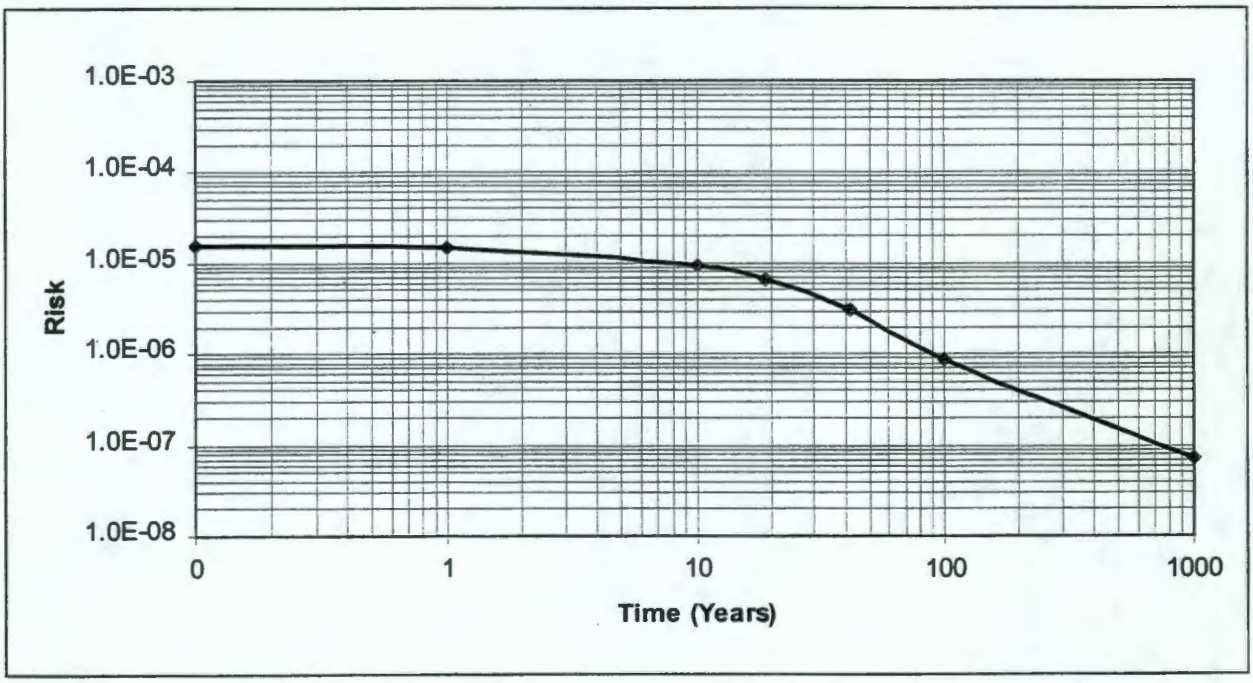
4.5.2 Nonradionuclides

The methodology for demonstrating the attainment of the Columbia River RAGs for nonradionuclides is summarized in Appendix B and in EPA/Ecology/RL meeting minutes (EPA et al. 1998; Ecology 1997). Site-specific calculations are presented in the calculation briefs found in Appendix C. The total and hexavalent chromium, lead, and mercury statistical values are below the protection of groundwater RAGs of 1,600 mg/kg, 8 mg/kg, 10.2 mg/kg, and 0.33 mg/kg, respectively, and therefore meet the groundwater protection and thus the Columbia River RAG for the entire 1,000-year time frame evaluated.

5.0 RADIONUCLIDE RISK INFORMATION

Because of radioactive decay, the risk associated with radionuclides decreases over time. The radionuclide excess cancer risk was calculated using the RESRAD model. The risk at each point in time is a plausible upper-bound lifetime probability of an individual developing cancer as a result of exposure to the radionuclides remaining at the site (EPA 1989). Based on RESRAD model results, the excess cancer risk is largest, 1.95×10^{-5} at present, and decreases to 8.39×10^{-8} in 1,000 years. The cumulative radionuclide risk in 19 years (the year 2018) is estimated at 5.73×10^{-5}. Figure 7 presents the results of the RESRAD risk estimate under the direct exposure scenario for all pathways.

Figure 7. RESRAD Analysis – Radionuclide Risk, All Pathways.



6.0 STATEMENT OF PROTECTIVENESS

As demonstrated in this verification package, the RAGs for direct exposure, groundwater protection, and surface water protection (including protection of the Columbia River) have all been achieved. Because the RAGs have been achieved, the RAOs that define the extent to which the waste sites require cleanup have also been met. Materials that contain COCs at concentrations that exceed the RAGs have been excavated, sampled, analyzed, and where required, the materials were removed and shipped to ERDF. The remaining soil has been sampled, analyzed, and modeled to show that no residual COC concentrations in vadose zone soils pose an unacceptable threat to human health, groundwater, or the Columbia River. The 116-B-13 site is thus verified to be remediated and no longer poses a threat to human health or the environment.

7.0 REFERENCES

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APPENDIX A

SUMMARY OF 116-B-13 VERIFICATION SOIL SAMPLING AND ANALYTICAL RESULTS

Table A-1. Summary of 116-B-13 Verification Soil Sampling and Analytical Data.

Samples			Isotopic Analysis				Gamma Scan					Liquid Scintillation		Total		ICP Metals	
Decision Unit	Composite Area	HEIS Number	Am-241 (pCi/g)	U-238 (pCi/g)	Pu-238 (pCi/g)	Pu-239/240 (pCi/g)	Co-60 (pCi/g)	Cs-137 (pCi/g)	Eu-152 (pCi/g)	Eu-154 (pCi/g)	Eu-155 (pCi/g)	Ni-63 (pCi/g)	Strontium (pCi/g)	Cr+6 (mg/kg)	Hg (mg/kg)	Cr (total) (mg/kg)	Lead (mg/kg)
Floor Samples (sampled on 11/23/98)																	
UNIT 1	A1	B0T0B5	0.0595	0.808 J	0.0107 UJ	0.0162 U	0.0165 U	0.0492	0.171 U	0.043 U	0.0022 U	3.05 U	0.105 U	0.03 U	0.02 J	3.0 J	0.960
	A2	B0T0D2	0.0276	0.793 J	-0.0012 UJ	0.0431 U	0.0123 U	0.0793	0.255 U	-0.0249 U	0.0401 U	5.33 U	0.407 J	0.03 U	0.02 J	4.1 J	1.5
	A3	B0T0D3	0.4930	0.746	0.0 UJ	0.0398	0.0172 U	0.0199 U	0.0980	-0.0614 U	0.0187 U	-0.108 U	0.0051 U	0.03 U	0.02 U	3.1	1.6
	A4	B0T0D4	0.3520	0.919	0.0053 UJ	0.0155 U	0.0172 U	0.0198 U	0.1380	-0.0054 U	0.0148 U	0.456 U	0.015 U	0.03 U	0.02 U	5.7	2.3
QA/QC Samples	Duplicate of B0T0B5	B0T0B6	0.0340	0.991 J	0.0033 UJ	0.0151 U	-0.0006 U	0.0342 U	0.043 U	0.0143 U	0.0137 U	3.53 U	0.0277 U	0.03 U	0.017 UR	2.5 J	1.1
	Split of B0T0B5	B0T0R9	0.0 U	0.580	-0.008 U	0.025 U	0.0 U	0.046 J	0.1100	0.0 U	0.0 U	1.7 U	0.006 U	0.84 U	0.02 U	2.50	4.4
	Equip Blank of B0T0B5	B0T0D5	0.025 U	0.278	-0.00043 UJ	0.0103 U	0.0021 U	0.00836 U	-0.0127 U	-0.0054 U	-0.0011 U	2.36 U	0.0093 U	0.03 U	0.02 U	0.08 U	0.32
EPA Split Samples	Split of B0T0B5	EPA-7	NA	0.968	-0.0203	0.0091	0.030	0.108	0.329	NA	NA	NA	NA	NA	0.0282U	1.64	1.53
	Split of B0T0D2	EPA-8	NA	0.696	0.0015	-0.0106	0.036	0.087	0.36	NA	NA	NA	NA	NA	0.0281U	3.08	2.25

NOTE: Negative radioactive results are measured as decay counts (e.g., counts per minute). An average background subtraction is applied, which may be more than the specific sample count; therefore, a negative result is possible.
U = Analyte is below the detection limits of the methods and instruments used (undetected).
R = Quality control indicates that the data are not usable (compound may or may not be present).
J = The associated value is an estimated quantity.
NA = Data not available.

APPENDIX B

ATTAINMENT OF REMEDIAL ACTION GOALS -- CALCULATION METHODOLOGIES

B1.0 ALL PATHWAYS

B1.1 RADIONUCLIDES

The single-tailed 95% upper confidence limit (UCL) was calculated for each radionuclide contaminant of concern (COC) on the arithmetic mean of the samples taken. For data qualified with a "U" (i.e., less than detection), the minimum detectable activity was used in the calculation of the 95% UCL. For data qualified with flags other than a "U," the reported value was used in the data set without adjustment. For the statistical evaluation of duplicate sample pairs, the samples are averaged before being included in the data set.

Naturally occurring background for uranium-238 was subtracted from the statistical value for shallow zone soils (no background is subtracted for all other radionuclides). This value became the statistical value above background and was used as the input value for RESidual RADioactivity Dose Model (RESRAD) analysis (ANL 1998).

To determine the attainment of the 15 mrem/yr cumulative radionuclide dose, RESRAD analysis (ANL 1998) was performed for the exposure pathways. The exposure pathways, as explained in the *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (RDR/RAWP) (DOE-RL 1998), are listed below:

- External gamma
- Inhalation
- Plant ingestion
- Meat ingestion
- Milk ingestion
- Aquatic foods ingestion
- Drinking water ingestion
- Soil ingestion.

The parameters, both generic and site-specific, needed for this analysis are listed in Appendix C. The generic parameters were taken directly from the RDR/RAWP (DOE-RL 1998).

B1.2 NONRADIONUCLIDES

Prior to calculation of the sample statistics, the nonradionuclide data below the detection limit were adjusted to one-half the detection limit value, as required by Washington State Department of Ecology (Ecology) guidance (Ecology 1993, WAC 173-340). Data qualified with anything but a "U" were included in the data set without adjustment. The single-tailed 95% UCL on the arithmetic mean was then calculated for each COC.

The statistical value used for cleanup verification was the 95% UCL on the mean, except in the following cases:

- Where more than 50% of the laboratory results were nondetects, the statistical value used was the maximum value of the data set.
- Where 100% of the laboratory results were nondetects, the statistical value used was the analytical method detection limit.

The statistical value for the COC was then compared to the cleanup criteria to evaluate attainment of direct exposure remedial action goals (RAGs).

B2.0 GROUNDWATER PROTECTION

An irrigation scenario of 76 cm/yr (30 in./yr) for 1,000 years was assumed when evaluating the potential impact of residual COC concentrations in soils to groundwater.

B2.1 RADIONUCLIDES

The RESRAD model was used to calculate the individual radionuclide concentration in groundwater that would result from the residual COC concentrations. If the site conceptual model breaks the contamination into multiple layers, the groundwater concentrations from the various layers are added to provide the concentration data for the dose calculation. For the 116-B-13 site, the conceptual model had only one layer. Table B-1 shows the estimated groundwater concentrations for the radionuclide COCs resulting from COCs in this layer. Only three of the radionuclide COCs (i.e., cobalt-60, cesium-137, and strontium-90) will reach groundwater.

To determine the groundwater concentrations, the assumptions in the RESRAD model for the drinking water pathway include:

- 0.76 m/yr (30 in./yr) irrigation
- 0.16 m/yr (6.3 in./yr) rainfall
- The contaminant concentrations at the base of the excavation continue to groundwater[1].

Table B-1 shows these concentrations for all the radionuclide COCs and the corresponding groundwater RAGs. If concentrations are below the RAG (true in this case), proceed to the next step in determining groundwater compliance.

[1]The K_d factors are as described in the RDR/RAWP (DOE-RL 1998) and shown in Table B-4.

Table B-1. RESRAD Estimated 116-B-13 Groundwater (Well Water/Drinking Water) Concentrations.

Radio-nuclide	Vadose Zone Horizon	Groundwater Concentration in pCi/L at Each Time Slice (year)							RAG from RDR/ RAWP
		0	1	10	19	42	100	1000	
Am-241		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.2
Co-60		0.000E+00	3.805E-05	1.173E-04	6.823E-05	7.323E-06	8.477E-09	0.000E+00	147
Cs-137		0.000E+00	1.821E-04	1.489E-03	2.298E-03	2.984E-03	1.857E-03	9.022E-12	120
Eu-152		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	235
Eu-154		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	59
Eu-155		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	587
Pu-238		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.6
Pu-239/240		0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.2
Sr-90		0.000E+00	7.430E-03	6.014E-02	9.217E-02	1.176E-01	7.005E-02	4.421E-11	8

The "National Primary Drinking Water Regulations" (40 CFR 141) establish a gross alpha particle activity standard of 15 pCi/L for alpma-emitting radionuclides (excluding radon and uranium). Because the alpha emitters (americium-241, plutonium-238, and plutonium-239/240) do not reach groundwater within 1,000 years, they meet the 15-pCi/L standard.

The "National Primary Drinking Water Regulations" (40 CFR 141) establish a 4-mrem/yr dose standard for beta- and gamma-emitting radionuclides in drinking water. They also specify the method of calculating dose: the individual organ-dose calculational method given in NBS Handbook 69 (NBS 1963). The radionuclide COCs that are beta or gamma emitters are cobalt-60, cesium-137, europium-152, europium-154, europium-155, and strontium-90.

To determine if any organ receives more than 4 mrem/yr dose, the dose to each organ was calculated from the COC radionuclide mixture.

There is a critical organ for each radionuclide (that is the organ that receives the highest dose from ingestion of that radionuclide). The critical organs for each radionuclide are determined from the maximum permissible concentrations (MPCs) given in Table 1 of NBS Handbook 69 (NBS 1963), and are denoted in bold in Table B-2. Calculate the factor C_4 (that is the concentration that will produce 4 mrem/y dose to that organ) for each organ and radionuclide. The equation for the calculation of C_4 for radionuclide A and organ x is

$$C_4^A(x) = 4.4 \times 10^6 \text{ (MPC/ORL)}$$

Table B-2. Factors for Calculating Radionuclide-Specific Organ Doses Using Methodology Mandated by the Safe Drinking Water Act for Comparison to the 4 mrem/yr Standard for Beta and Gamma Emitters.

Radionuclide	Organ	C_4 Factor[a]
Co-60	**GI(LLI)[2]**	100
	Total Body	900
	Liver	3000
Cs-137	Bone	80
	GI(LLI)	2000
	Total Body	200
	Liver	60
Eu-152	Bone	1E +07
	GI(LLI)	200
	Total Body	2E+08
	Liver	2E+07
Eu-154	Bone	5000
	GI(LLI)	60
	Total Body	7E+04
	Liver	6E+04
Eu-155	Bone	1E+05
	GI(LLI)	600
	Total Body	9E+05
	Liver	6E+05
Sr-90	**Bone**	8
	GI(LLI)	100
	Total Body	8

[a]Factor calculated by methodology given in EPA-570/9-76-003, *National Interim Primary Drinking Water Regulations*, Appendix IV, "Dosimetric Calculations for Man-Made Radioactivity," Section A (EPA 1997). This number is unitless.
GI(LLI) = Gastrointestinal tract, lower large intestine
Critical organs are shown in bold.

The term ORL is the occupational radiation limit (in rems) for the organ given in the *National Primary Drinking Water Regulations* (EPA 1976). The ORLs for the individual organs are:

- Total body - 5
- Gonads - 5
- Thyroid - 30
- Bone - 29.1
- Other organs – 15.

The C_4 factors for the 116-B-13 COCs are summarized in Table B-2.

The cumulative dose for each organ at time t needs to be calculated separately and the sum of fractions equation (EPA 1976) calculated as shown below. If a radionuclide does not have an MPC for the organ of interest, the C4 factor for total body dose is used in the calculation. The calculations performed are documented in a calculation brief (0100B-CA-V0041) referenced in Appendix C. The organs for which doses need to be computed are total body, bone, and gastrointestinal tract (lower large intestine) [GI(LLI)]. The individual organ doses are compared to 4 mrem/yr. With this methodology, one does not sum doses for different organs for the comparison to 4 mrem/yr.

$$Dose_{organ\ x}(t) = [ConcA(t)/C_4^A(x) + ConcB(t)/C_4^B(x) + \ldots] \times (4\ mrem/yr)$$

If the dose for organ x is less than 4 mrem/yr, then the standard is met. Table B-3 provides organ doses from groundwater.

Table B-3. Organ Doses (in mrem/yr) from 116-B-13 Beta and Gamma Emitters

Organ	Time (years)						
	0	1	10	19	42	100	1000
Bone	0	2.82E-03	2.28E-02	3.50E-02	4.46E-02	2.66E-02	1.74E-11
GI(LLI)	0	2.29E-04	1.83E-03	2.80E-03	3.57E-03	2.13E-03	1.37E-12
Total Body	0	2.81E-03	2.28E-02	3.49E-02	4.46E-02	2.66E-02	1.71E-11
Liver	0	1.11E-05	9.04E-05	1.39E-04	1.80E-04	1.12E-04	5.46E-13

B2.2 NONRADIONUCLIDES

If the statistical value of a COC is below the background value, the COC is not considered further in the groundwater protection evaluation, and the groundwater protection RAG is considered to be attained.

To determine the RAG for contaminants in soil that is protective of groundwater, the "100 times maximum contamination level (MCL)" rule is applied (as a first test) to the groundwater MCL (or relevant action level) for each COC. Application of the "100 times MCL" rule involves a conversion of groundwater action levels (µg/L) to equivalent soil action levels (mg/kg). This calculation is based on a kg/L density conversion factor assumption. The "100 times MCL" rule is applied in accordance with *Washington Administrative Code* (WAC) 173-340-740(3)a. For example, a RAG of 1 µg/L has a corresponding soil equivalent RAG of 0.1 mg/kg (e.g., 1 µg/L = 0.001 mg/L, 0.001 mg/L ÷ 1 kg/L = 0.001 mg/kg, 100 x 0.001 mg/kg = 0.1 mg/kg). After conversion of the groundwater action level to a soil equivalent value, the COC statistical values can be compared directly to the RAG soil equivalent value. Per WAC 173-340-740(3)a, the COC statistical values that are less than the RAG soil equivalent value are considered protective of the groundwater.

For hexavalent chromium, a RAG of 8 mg/kg and 2.2 mg/kg (soil value) has been set by the U.S. Environmental Protection Agency (EPA) and Ecology (EPA et al. 1997, Ecology 1997) as protective of the groundwater and the Columbia River. The statistical value is then compared to this RAG to demonstrate attainment of groundwater protection for hexavalent chromium.

If the statistical value of a COC is determined to be equal to the analytical method practical quantitation limit (PQL), which is the lowest detectable value, but the PQL is greater than the cleanup RAG, the RAG is considered to have been attained in accordance with WAC 173-340-707. For example, the MCL for polychlorinated biphenyls (PCBs) is 0.01 µg/L (or 0.00001 mg/L), which after applying the "100 times rule," provides a soil RAG of 0.001 mg/kg. Direct comparison of the statistical value to this soil RAG is inappropriate because the PQL at which PCBs are detectable is greater than 0.001 mg/kg. Therefore, in this case, the PQL for PCB analysis and the corresponding statistical value is considered protective of the groundwater. In cases where the COC analytical PQL is below the RAG, the statistical value is directly compared to the soil equivalent RAG.

Application of the "100 times MCL" rule represents a conservative scenario in that the COC soil concentrations are assumed to extend uniformly from the bottom of the excavation to the groundwater. If attainment of the groundwater RAGs is not met under the "100 times MCL" rule, a more detailed site-specific evaluation is performed, using RESRAD modeling. Nonradionuclide COCs are modeled by using an equivalent radionuclide surrogate with a long half-life (>1,000 years) with the distribution coefficient (K_d) set at the actual K_d of the nonradionuclide constituent. The resulting groundwater concentration calculated by RESRAD is then compared directly to the action levels for groundwater.

Table B-4 presents the K_d values from the RDR/RAWP (DOE-RL 1998).

Table B-4. Distribution Coefficient (K_d) Values. (2 pages)

Contaminant	Distribution Coefficient (mL/g)
Am-241	200
Co-60	50
Cs-137	50
Eu-152	200
Eu-154	200
Eu-155	200
Pu-238	200
Pu-239/240	200
U-238	2

Table B-4. Distribution Coefficient (K_d) Values. (2 pages)

Contaminant	Distribution Coefficient (mL/g)
Sr-90	25
Chromium (III)	200
Chromium (VI)	0
Mercury	30
Lead	30

Source: *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE-RL 1998).

B3.0 COLUMBIA RIVER PROTECTION

B3.1 RADIONUCLIDES

The individual radionuclide Columbia River RAG is equivalent to the groundwater RAG[1]; therefore, if the individual radionuclide groundwater RAG is attained, the individual Columbia River RAG is also attained. Methodology for attainment of the radionuclide groundwater RAGs is described in Section B2.1. Where the groundwater RAG is not attained, the surface water protection action levels are multiplied by the dilution attenuation factor (DAF) for each individual radionuclide. This accounts for half-life decay, transport time, and dilution at the groundwater/Columbia River interface. Calculation of the DAF is described in the RDR/RAWP (DOE-RL 1998). If contaminants do not reach the Columbia River in concentrations exceeding the action levels times the DAF, then Columbia River RAGs are attained.

B3.2 NONRADIONUCLIDES

If the statistical value of a COC is below the background value, it is not considered further in Columbia River protection cleanup verification evaluation, and the Columbia River RAG has been attained.

To determine the RAG for nonradionuclide contaminants in soils that is protective of the surface water, the "100 times MCL times DAF" rule was applied (as a first test) to the surface water protection action level for each COC. Application of the "100 times MCL times DAF" rule involves a conversion of surface water protection action levels (µg/L) to equivalent soil action levels (mg/kg). This calculation is based on a 1 kg/L density conversion factor assumption. A DAF based on a dilution of 1:1 has been established

[1]Because there are no ambient water quality criteria for radionuclides, the groundwater action levels apply to river protection.

in the RDR/RAWP (DOE-RL 1998) for nonradionuclides. The "100 times MCL times DAF" rule is then applied to provide a soil equivalent RAG that is protective of the Columbia River. The statistical value is then directly compared to the soil equivalent RAG for surface water protection. If the statistical value is lower, the Columbia River RAGs are attained.

For hexavalent chromium, a RAG of 2.2 mg/kg (soil value) has been set by EPA and Ecology (EPA et al. 1997, Ecology 1997) that is protective of the groundwater and the Columbia River. The statistical value is then compared to the RAG to show attainment of Columbia River protection for hexavalent chromium.

If the statistical value of a COC is determined to be equal to the analytical method PQL, but the PQL is greater than the cleanup RAG, the RAG is considered to have been attained in accordance with WAC 173-340-707. For example, the ambient water quality criterion for PCBs is 0.014 µg/L (or 0.000014 mg/L), which after applying a DAF and the "100 times rule," provides a soil RAG of 0.0028 mg/kg. In this case, a direct comparison of the statistical value to the RAG of 0.0028 mg/kg is not done because the PQL for PCB analysis (i.e., statistical value) is considered protective of the Columbia River.

If the Columbia River RAG is not attained by these methods, then the statistical values are modeled using RESRAD (as described in Section B2.2) to determine if nonradionuclides reach the groundwater within 1,000 years after remediation. If these nonradionuclides do not reach the groundwater, then they do not reach the Columbia River; thus, Columbia River RAGS are attained.

If RESRAD modeling indicates that contaminants do reach the groundwater within 1,000 years, the travel time in the groundwater underlying the site to the Columbia River is estimated. If contaminants do not reach the Columbia River within 1,000 years in concentrations exceeding the RAGs, then Columbia River remedial action objectives are attained.

B4.0 RISK INFORMATION

B4.1 RADIONUCLIDE CONTAMINANTS OF CONCERN

Radionuclides are carcinogenic COCs. The RESRAD computer model, which is used to assess dose over time, is also used to provide an estimate of incremental and cumulative cancer risk over time. The details of the risk estimation are provided in the RESRAD calculation briefs (see Appendix C).

B4.2 NONRADIONUCLIDE CONTAMINANTS OF CONCERN

The *Model Toxics Control Act* (MTCA) requires the evaluation of risk for multiple pathways of exposure and multiple contaminants. The procedures discussed in this section provide the needed risk information for purposes of the report. Upon the completion of the remedial action of individual waste sites within each 100 Area operable unit, a formal baseline risk assessment will be performed for the entire operable unit or reactor area.

B4.2.1 Noncarcinogens

For noncarcinogenic COCs, MTCA specifies the use of the hazard quotient, which is defined as daily intake divided by a reference dose (DOE-RL 1995). The hazard index or cumulative hazard quotient is the sum of the hazard quotients for the individual COCs.

For purposes of this report, the hazard quotient requirement was addressed as follows. The MTCA Method B cleanup limits were set to be compliant with a hazard quotient of 1.0; therefore, the ratio of the statistical value from the verification samples to the direct exposure RAG (lookup value obtained from the RDR/RAWP [DOE-RL 1998]) provides a conservative approach for addressing the hazard quotient. The fraction of cleanup level (Fc) is calculated as follows:

$$Fc = S/V$$

where:
- Fc = fraction of cleanup level (dimensionless)
- S = statistical value of the COCs (in mg/kg)
- V = lookup value (MTCA Method B derived, direct exposure RAG in mg/kg).

If the Fc is less than 1 for an individual COC, then the hazard quotient has been addressed.

For multiple COCs, a sum of the individual COC Fc values was used to address the hazard index. The Fc values for all noncarcinogenic COCs were summed. If that sum was less than 1, then the hazard index had been addressed.

B4.2.2 Carcinogens

For individual nonradionuclide carcinogenic COCs, the MTCA Method B cleanup limits are based on an incremental cancer risk of 1×10^{-6}. If a linear relationship is assumed between environmental concentration and risk, the ratio (Fc) of the statistical value from the verification samples divided by the MTCA Method B limit, multiplied by 10^{-6}, is an estimate of the risk associated with the statistical value.

For multiple carcinogenic COCs, the risks of the individual COCs (described above) are summed. If no risk associated with a single COC exceeds 1×10^{-6} and if the sum of the

individual COC risk does not exceed 1 x 10^{-5}, then the MTCA Method B risk requirement has been addressed for this remedial action.

B5.0 REFERENCES

40 CFR 141, "National Primary Drinking Water Regulations," *Code of Federal Regulations*, as amended.

ANL, 1998, *RESRAD for Windows*, Version 5.82, Argonne National Laboratory, Environmental Assessment Division, Argonne, Illinois.

DOE-RL, 1995, *Hanford Site Risk Assessment Methodology*, DOE/RL-91-45, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland Washington.

DOE-RL, 1998, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, DOE/RL-96-17, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Ecology, 1993, *Statistical Guidance for Ecology Site Managers,* Ecology Publication 92-64, Supplement S-6, "Analyzing Site or Background Data with Below-Detection Limit or Below PQL Values (Censored Data Sets)," Washington State Department of Ecology, Olympia, Washington.

Ecology, 1997, *100 Area RAG for Cr+6*, CCN 056430, memorandum to C. C. Corriveau, Bechtel Hanford, Inc., dated March 25, 1997, Washington State Department of Ecology, Kennewick, Washington.

EPA, 1976, *National Primary Drinking Water Regulations*, EPA-570-76-003, U.S. Environmental Protection Agency, Washington, D.C.

EPA, Ecology, and RL, 1997, *Environmental Restoration Contractor Meeting Minutes, March 10, 1997 Meeting – 100 Area Cr+6 in Soils*, CCN 045191, U.S. Environmenta Protection Agency, Washington State Department of Ecology, and U.S. Department of Energy, Richland Operations Office, Richland, Washington.

NBS, 1963, *Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure*, NBS Handbook 69, as amended, National Bureau of Standards, Washington, D.C.

WAC 173-340, "Model Toxics Control Act – Cleanup," *Washington Administrative Code*, as amended.

APPENDIX C

CALCULATION BRIEF COVERSHEETS AND RESRAD INPUT PARAMETERS

CALCULATION BRIEFS

The following calculation briefs have been prepared in accordance with BHI-DE-01, *Design Engineering Procedures Manual*, EDPI-4.37-01, "Project Calculations," Bechtel Hanford, Inc., Richland, Washington.

BHI, 1998, *116-B-13 Variance Calculation*, Calculation No. 0100B-CA-V0023, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

BHI, 1998, *116-B-13 Shallow Zone Sampling Locations*, Calculation No. 0100B-CA-V0024, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

BHI, 1999, *116-B-13 95% UCL Calculations for Compliance with Cleanup Standards*, Calculation No. 0100B-CA-V0056, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

BHI, 1999, *RESRAD Calculations Supporting Closeout of the 116-B-13 Remediation Site*, Calculation No. 0100B-CA-N0009, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

Also attached are (1) the RESRAD input parameters for the shallow zone and (2) RESRAD input parameters for lead in the shallow zone.

BHI, 1999, *116-B-13 Comparison to Drinking Water Standards*, Calculation No. 0100B-CA-V0041, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.

NOTE: The calculation briefs referenced in this appendix are kept in the active Environmental Restoration Contractor project files and are available upon request. When the project is completed, the files will be stored in a U.S. Department of Energy, Richland Operations Office repository. Also note that only excerpts of the calculation briefs are included in this appendix.

CALCULATION COVER SHEET

Project Title:	100-BC Remedial Action	**Job No.**	**22192**
Area	100-B		
Discipline	Environmental	***Calc. No.**	0100B-CA-V0023
Subject	116-B-13 Variance Calculation		
Computer Program	Excel	**Program No.**	Excel 97

Committed Calculation **Preliminary** **Superseded**

Rev.	Sheet Numbers	Originator	Checker	Reviewer	Approval	Date
0	Cover - 1 Total - 6	R.B. Kerkow RBK R.B. Kerkow 11/17/98	ID Jacques Duane Jacques 11-18-98	M.H. STURGES M.H. Sturges 11/19/98	FM Corpuz FM Corpuz 11/23/98	11/23/98

SUMMARY OF REVISIONS

Scanned	Rev.	Date	Bar Code No.

* Obtain Calc. No. from DIS.

CALCULATION SHEET

Originator	R. B. Kerkow RBK	Date	11/17/98	Calc. No.	0100B-CA-V0023	Rev. No.	0
Project	100-BC Remedial Action	Job No.	22192	Checked	[illegible]	Date	11-18-98
Subject	116-B-13 Variance Calculation					Sheet No.	1 of 5

Problem:

Perform a sample variance calculation to determine the number of samples required for 116-B-13 shallow zone (Sample Area "A") verification sampling as required in DOE/RL-96-22, Rev. 1, "100 AREA REMEDIAL ACTION SAMPLING AND ANALYSIS PLAN" (SAP); and Instruction Guide (IG) 0100X-IG-G0001, Rev. 1, "INSTRUCTION GUIDE FOR THE REMEDIATION OF THE 100-BC-1, 100-DR-1, AND 100-HR-1 WASTE SITE.

Given:

1) Sample locations for 116-B-13 (Sample Area "A") from Calculation No. 0100B-CA-V0024, Rev. 0.
2) Results of Gamma Energy Analysis (GEA) provided by Radiological Counting Facility (RCF).
3) Lookup values from DOE/RL-96-22.
4) Requirements from DOE/RL-96-22 and 0100X-IG-G0001.

Solution:

Calculation methodology is described in DOE/RL-96-22, Attachment A-1. Variance calculation is based on the same three isotopes used to develop the statistical approach in DOE/RL-96-22. The statistical design is based on the premise that these isotopes are the predominant components of the contamination and are representative of the contamination distribution. Although analytical results are available for other isotopes, this information is not considered applicable or appropriate for the purpose of this calculation.

Sheet No.	Sheet Title	Topic
1	Calc. Summary	Summary overview of calculation brief.
2	Variance	Variance calculation to compute the number of verification samples required.
3	Formulas	Excel spreadsheet formulas used to perform the variance calculation.
4	Data Summary	Sample ID, sample location, and data for selected analytes.
5	Sample Results	Gamma energy analysis results, reported by Radiological Counting Facility.

Calculations and Data sheets are interlinked within the spreadsheet such that a change in the data will effect the calculation. An "=IF" statement is used in column j of the "Shallow Zone Formulas" spreadsheet to verify that the sample ID (HEIS number) is correctly assigned to the appropriate analytical result.

Conclusion:

The required number of samples for the 116-B-13 Shallow Zone, Sample Area "A" is less than the default number (4 samples) specified in DOE/RL-96-22, therefore, the default number of samples will be collected.

Variance
CALCULATION SHEET

Originator	R. B. Kerkow RBK	11/17/98	**Calc. No.**	0100B-CA-V0023	**Rev. No.** 0
Project	100-BC Remedial Action	22192	**Checked**		**Date** 11-18-98
Subject	116-B-13 Variance Calculation				**Sheet No.** 2 of 5

1 **Statistical Evaluation of Analytical Data**
2 The required number of samples resulting from the calculation is highlighted at the bottom of the page.
3 Each value is reflective of the specific isotope evaluated.
4 The highest value of the three evaluations is used to determine the required number samples as compared against the default of four.
5
6
7 **Shallow Zone**
8 Samples values from Gamma Energy Analysis (GEA) in pCi/g.
9

10 **Sample Area "A"**				**Constituent**			
11 **Sample #**	**Location**	**Co60**		**Cs137**		**Eu152**	
12 **Look-up Value===>**		**1.40E+00**		**6.20E+00**		**3.30E+00**	
13 B0T1W3	A1-02	3.60E-02	U	4.40E-02	U	2.60E-01	U
14 B0T1W4	A1-03	4.50E-02	U	5.80E-02	U	2.20E-01	U
15 B0T1W5	A1-04	1.00E-01	U	4.40E-02	U	3.90E-01	U
16 B0T1W6	A1-10	1.10E-02	U	8.40E-02		4.00E-01	U
17 B0T1W7	A1-13	4.30E-02	U	4.30E-02	U	2.90E-01	U
18 B0T1W8	A1-16	5.60E-02	U	4.60E-02	U	4.70E-01	U
19 B0T1W9	A2-03	6.50E-02	U	3.60E-02	U	3.70E-01	U
20 B0T1X0	A2-06	8.00E-02	U	1.10E-01		5.60E-01	
21 B0T1X1	A2-07	4.20E-02		5.30E-02	U	2.00E-01	U
22 B0T1X2	A2-10	8.60E-02	U	4.40E-02	U	3.60E-01	U
23 B0T1X3	A2-14	8.40E-02	U	4.00E-02	U	7.30E-01	
24 B0T1X4	A2-15	3.70E-02	U	2.60E-02	U	2.90E-01	U
25 B0T1X5	A3-01	3.00E-02	U	2.80E-02	U	1.80E-01	U
26 B0T1X6	A3-02	3.00E-02	U	3.00E-02	U	2.40E-01	U
27 B0T1X7	A3-04	1.10E-02	U	6.20E-02	U	2.00E-01	U
28 B0T1X8	A3-05	6.80E-02	U	6.10E-02	U	4.00E-01	U
29 B0T1X9	A3-09	6.90E-02	U	4.70E-02	U	3.40E-01	U
30 B0T1Y0	A3-11	8.90E-02	U	5.20E-02	U	3.70E-01	U
31 B0T1Y1	A4-03	7.70E-02		1.20E-01		9.30E-01	
32 B0T1Y2	A4-04	4.60E-02	U	2.50E-02	U	2.50E-01	U
33 B0T1Y3	A4-07	7.80E-02	U	4.80E-02	U	3.30E-01	U
34 B0T1Y4	A4-09	5.10E-02		4.80E-02		2.70E-01	
35 B0T1Y5	A4-12	6.30E-02		1.20E-01		2.70E-01	U
36 B0T1Y6	A4-13	9.10E-02	U	6.70E-02	U	9.50E-01	
37 Mean==========>		5.78E-02		5.57E-02		3.86E-01	
38 Standard Deviation=>		2.52E-02		2.72E-02		2.10E-01	
39 τ ==========>		5.33E+01		2.26E+02		1.39E+01	
40 **Number of Samples>**		**2.18E-03**		**1.21E-04**		**3.22E-02**	

CALCULATION COVER SHEET

Project Title 116-B-13 Shallow Zone Area Sampling Locations **Job No.** 22192
Area 100 BC-1 Operable Unit
Discipline Environmental ***Calc. No.** 0100B-CA-V0024
Subject 116-B-13 Shallow Zone Area Sampling Locations
Computer Program NA **Program No.** NA

Committed Calculation ☑ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Reviewer	Approval	Date
0	4	C.A. Bentz 11/11/98	RT. Coffman 11/11/98	~~K.E. Cook~~ M.H. Sturges 11/19/98	F.M. Corpuz 11/23/98	11/23/98

SUMMARY OF REVISION

Scanned:	Rev.	Date	Bar Code No.	Rev.	Date	Bar Code No.

*Obtain Calc. No. from DIS.

CALCULATION SHEET

Originator	C.A. BENTZ CAB	Date	11/4/98	Calc. No.	0100B-CA-V0024	Rev. No.	0
Project	100-BC	Job No.	22192	Checked	RTC	Date	11-5-98
Subject	116-B-13 Shallow Zone Area Sampling Locations					Sheet No.	2 of 4

Problem: Calculate and display required sampling nodes in concurrence with 100 Area SAP DOE/RL-96-22 Rev. 0 for verification and closure.

Given: -SAP (DOE/RL-96-22 Rev. 0) and FIG (0100X-IG-G0001 Rev. 1) requirements
-Shallow Sampling Area (Surface area of each zone determined from CAD program, using Figure 1, attached)

SAP and FIG Requirements:

Shallow Zone:
-Develop a 16 node sampling grid for the sampling area
-Use appendix A of the FIG to determine which six of the sixteen will be sampled to collect HPGe and closeout data

Determination of Shallow Zone Sampling Grid:

Shallow Zone Sampling Grid Area determined from Table 5-1, FIG
Number of Decision Subunits Based on Area

Total Area:	791.0	m^2
Area of Decision Subunit 1:	791.0	m^2
Decision Subunit 1 divided into 4 Sampling Areas:	197.8	m^2
Sampling Areas divided into a 16 node grid (node numbers 1-16):	12.36	m^2

Nodes to be Sampled (as determined from Table A-1 in the FIG, Attach. 1):
See Figure 1, 116-B-13 Shallow Zone Sampling Plan, for Sample Location Table

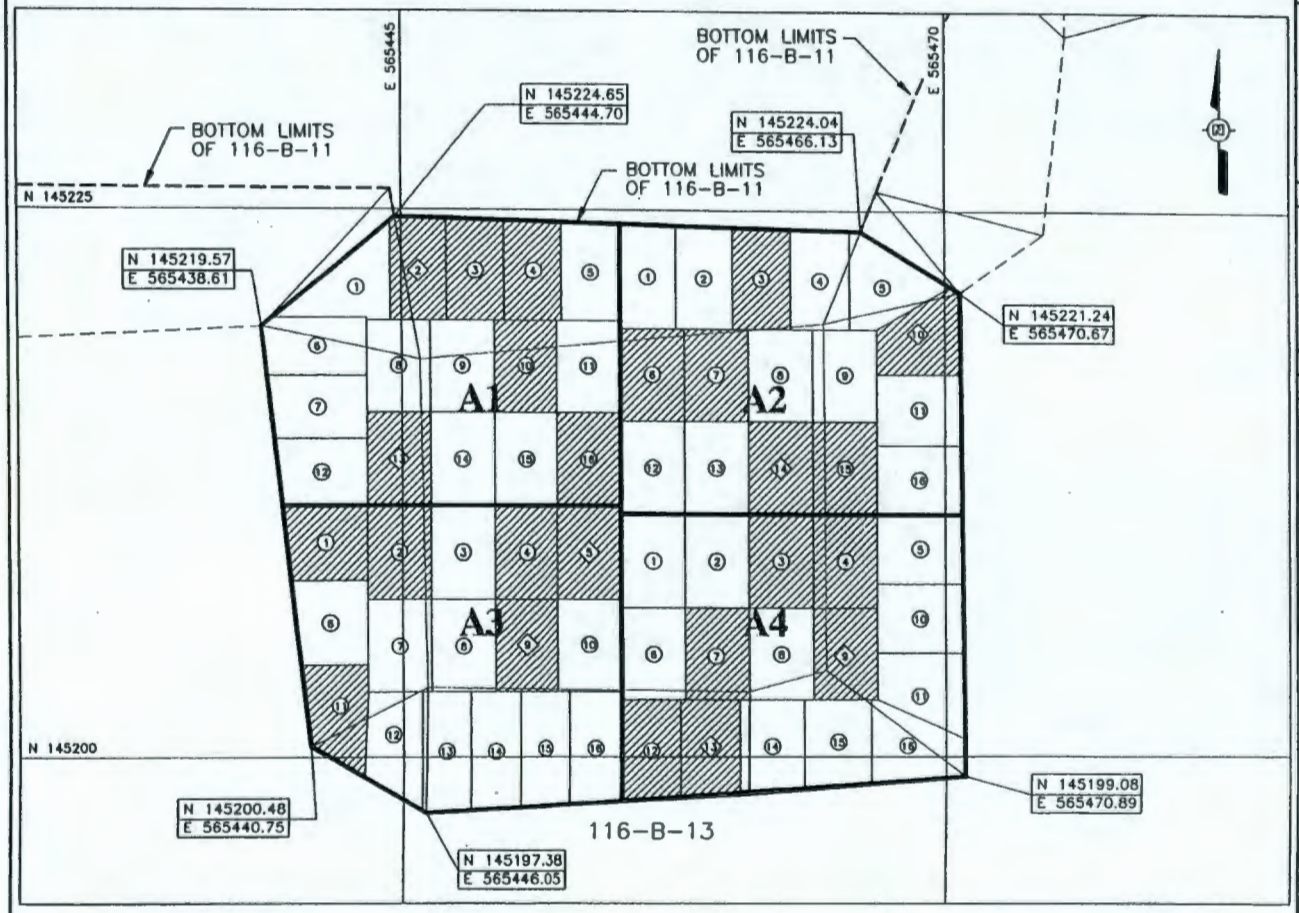
Table A-1. Sample Grid Point Lookup Table.

Default Plan	Sampling Area 1	Sampling Area 2	Sampling Area 3	Sampling Area 4	Sampling Area 5	Sampling Area 6	Sampling Area 7	Sampling Area 8	Sampling Area 9	Sampling Area 10
HPGe/Closeout	3	6	1	4	5	1	3	3	4	16
HPGe/Closeout	4	7	11	3	15	15	5	13	10	10
HPGe/Closeout	16	3	2	7	7	10	11	4	3	14
HPGe/Closeout	10	15	4	12	1	13	4	8	16	4
HPGe	2	14	5	9	13	12	8	2	14	8
HPGe	13	10	9	13	2	16	1	12	5	3
Not sampling	6	1	10	8	14	4	16	5	8	6
Not sampling	1	9	13	1	10	5	12	1	1	15
Not sampling	9	12	7	5	6	2	6	7	15	9
Not sampling	15	16	15	14	16	6	2	15	11	1
Not sampling	8	13	8	10	12	11	13	14	2	12
Not sampling	5	2	3	11	4	3	9	10	7	11
Not sampling	7	11	14	15	11	14	14	6	13	2
Not sampling	11	4	6	2	9	7	7	11	9	7
Not sampling	12	8	16	16	3	8	15	9	6	13
Not sampling	14	5	12	6	8	9	10	16	12	5

**NOTE: Grid nodes for each sampling area in each waste site should be numbered consistently, e.g., begin numbering the nodes in the northwesternmost node. Then number consecutively left to right as shown in Figure 5-1 of this FIG.

Originator	C.A. BENTZ	Date	11/05/98
Calc. No.	0100B-CA-V0024	Rev. No.	0
Project	100 Area Remedial Design	Job No.	22192
Chk'd By	RTC	Date	11-5-98
Subject	116-B-13 SHALLOW ZONE SAMPLING LOCATIONS		
		Sheet No.	3 of 4

1B:110498A



SCALE 1:200

2 0 2 4 8

1 cm = 2 meters

Originator	C.A. BENTZ CAB	Date	11/04/98
Calc. No.	01008-CA-V0024	Rev. No.	0
Project	100 B/C Area Remedial Design	Job No.	22192
Chk'd By	KV	Date	11/4/98
Subject	116-B-13 SHALLOW ZONE AREA SAMPLING LOCATIONS		
		Sheet No. 4 of 4	

NOTES

1. SHALLOW ZONE NODE AREAS ARE APPROXIMATELY 12.36 SQUARE METERS.
2. MEASUREMENTS OF EACH NODE WITHIN DECISION UNIT 1 VARY.
3. SAMPLES WILL BE TAKEN FROM THE APPROXIMATE CENTER OF EACH NODE.
4. THE SHALLOW ZONE CONSISTS OF SAMPLING AREAS A1, A2, A3 AND A4 WITHIN DECISION UNIT 1.

LEGEND

CLOSEOUT VERIFICATION SAMPLING NODE

GAMMA ENERGY ANALYSIS SAMPLING NODE

SAMPLE LOCATION TABLE

DECISION UNIT	SAMPLING AREA	SAMPLE NODE	NORTHING	EASTING
UNIT 1	A1	A1-2	145222.17	565445.78
		A1-3	145222.18	565448.40
		A1-4	145222.18	565451.08
		A1-10	145217.76	565450.71
		A1-13	145213.54	565444.84
		A1-16	145213.54	565453.85
UNIT 1	A2	A2-3	145221.85	565461.61
		A2-6	145217.39	565456.58
		A2-7	145217.39	565459.53
		A2-10	145219.31	565488.77
		A2-14	145213.17	565462.46
		A2-15	145213.17	565465.39
UNIT 1	A3	A3-1	145209.73	565441.43
		A3-2	145209.33	565444.84
		A3-4	145208.32	565450.71
		A3-5	145208.33	565453.85
		A3-9	145203.17	565450.71
		A3-11	145202.37	565442.06
UNIT 1	A4	A4-3	145208.95	565462.46
		A4-4	145208.95	565465.39
		A4-7	145204.66	565459.47
		A4-9	145204.67	565465.33
		A4-12	145200.28	565456.47
		A4-13	145200.60	565459.25

FIGURE 1

U.S DEPARTMENT OF ENERGY
DOE FIELD OFFICE, RICHLAND
HANFORD ENVIRONMENTAL RESTORATION PROGRAM

100 B/C AREA
100 AREA REMEDIAL DESIGN
116-B-13 SHALLOW ZONE SAMPLING PLAN

CVP-99-00002
Rev. 0

CALCULATION COVER SHEET

Project Title:	116-B-13 Site Closeout	**Job No.**	22192
Area	100-B		
Discipline	Environmental	***Calc. No.**	0100B-CA-V0056
Subject	116-B-13 95% UCL Calculations for Compliance with Cleanup Standards		
Computer Program	Excel	**Program No.**	Excel 97

Committed Calculatio X **Preliminary** **Superseded**

Rev.	Sheet Numbers	Originator	Checker	Reviewer	Approval	Date
0	9	K.E. Cook 5/10/99 KEC FOR D. B. Blumenkranz	T. B. Miley 5/10/99 T. B. Miley	J.D. Fancher 5/11/99 J. D. Fancher	F.M. Corpuz 5-11-99 F. M. Corpuz	5-11-99

SUMMARY OF REVISIONS

This calculation supercedes calculation # 0100B-CA-V0025, Rev. 0.

Scanned	Rev.	Date	Bar Code No.

Bechtel Hanford, Inc. **ERC TEAM**

CALCULATION SHEET

Originato	D. B. Blumenkranz KBB FOR	**Date**	05/10/1999	**Calc. No.**	0100B-CA-V005	**Rev. No.**	0
Project	116-B-13 Site Close	**Job No.**	22192	**Checked**	S. Miley	**Date**	5/10/99
Subject	116-B-13 95% UCL Calculations for Compliance with Cleanup Standards					**Sheet No.**	1 of 8

Problem:
Calculate the requisite statistics to evaluate compliance with cleanup standards for 116-B-13 shallow zone soils as required by the Field Instruction Guide (FIG) (100-IG-G0001, Rev. 1); these statistical values will also be used to determine compliance with groundwater and river protection criteria. Also calculate the risk for nonradioactive analytes and the statistical power of the sample set to determine if the error tolerance established in the SAP (at least 80%) has been met.

Given:
1) Sample Results
2) Lookup values from Remedial Design Report/Remedial Action Work Plan (RDR/RAWP) (DOE/RL-96-17, Rev. 0)
3) Requirements from the 100-Area Remedial Action Sampling and Analysis Plan (SAP) (DOE/RL-96-22, Rev. 0, and FIG
4) Model Toxics Control Act, Washington Administrative Code-173-340, and Statistical Guidance for Ecology Site Managers, Ecology Pub. #92-64, Washington Department of Ecology, Olympia, Washington.
5) Ecology, 1993, *Statistical Guidance for Ecology Site Managers*, Supplement S-6, Analyzing Site or Background Data with Below-detection Limit or Below-PQL Values (Censored Data Sets).

Solution:
Calculation methodology is described in Ecology Pub. #92-64, below, and in Attachment A-1 of the SAP. Use data from attached worksheets to calculate the single-tailed upper 95% confidence limit on the mean for each analyte. Compare this value for nonradionuclides to the cleanup standard in the RDR/RAWP. Compute the sum of the quotients for noncarcinogenic nonradionuclides and the risk associated with carcinogenic nonradionuclides. Use the data to compute the power achieved with the number of samples collected and compare to requirements in the SAP (20% false-negative error rate).

Calculation Description:
The subject calculations were performed on data from soil verification samples from waste site 116-B-13. The data were entered into an EXCEL 97 spreadsheet and calculations performed by utilizing the built-in spreadsheet functions and/or creating formulae within the cells. The statistical evaluation of data for use in accordance with the RDR/RAWP is documented by this calculation.

Methodology:
The statistical value calculated to evaluate the effectiveness of cleanup was the 95% UCL on the mean. For analytes with > 50% of the data below detection limits, the maximum value for the sample data was used instead of the 95% UCL. All nonradionuclide (i.e., metals and chemicals) data reported as being below detection limit were set to ½ the detection limit value for calculation of the statistics (Ecology, 1993). For radionuclide data, calculation of the statistics was done on the reported value, OR USING the MINIMAL detectable activity for those analytes below detection. KBM 7/20/99

Natural background activity was subtracted from the statistical value for ^{238}U (a naturally occurring radionuclide). For nonradionuclides, the 95% UCL was calculated to compare directly with the appropriate cleanup values, and the other 2 parts of the MTCA test (no sample greater than 2 times the cleanup value and less than 10% of the samples above the cleanup value). To further evaluate the nonradionuclide closeout data, the fraction statistical value/cleanup limit was calculated and summed. This sum of the quotients is similar to a hazard quotient, where values <1 are considered protective of human health. The nonradionuclide carcinogenic risk was calculated by multiplying the carcinogenic quotient for Cr+6 (the only carcinogenic nonradionuclide) by E-06, which is the risk associated with the cleanup limits for chemicals and metals. The risk associated with radionuclides is determined in a separate calculation using RESRAD.

For the statistical evaluation of duplicate sample pairs, the samples are averaged before being included in the data set. An exception is made for nonradionuclides based on detection limit considerations. If both of the duplicate pairs are below the detection limit, the average of half the detection limit is computed. If one of the nonradionuclide samples is above and the other below the detection limit, the detected sample is averaged with half the detection limit of the undetected sample.

The MTCA statistical guidance suggests that a test for distributional form be performed on the data, and the 95% UCL calculated on the appropriate distribution. However, these for small data sets, MTCA recommends that the calculations be performed assuming a normal distribution. For those constituents where the majority of the data were below the detection limit, the statistical value used was the maximum value, and the distribution of the data has no influence on the tests for compliance.

To determine if the number of samples collected satisfies the confidence levels determined in the SAP (i.e., false-negative error=20%), the formula in Appendix A (p. A-2) of the SAP was used. Values below detection limit were treated in the same manner as described above.

Bechtel Hanford, Inc. **ERC TEAM**

CALCULATION SHEET

Originato	D. B. Blumenkranz KEC FOR	**Date** 05/10/1999	**Calc. No.** 0100B-CA-V005	**Rev. No.**	0
Project	116-B-13 Site Close	**Job No.** 22192	**Checked** J. Miley	**Date**	5/10/99
Subject	116-B-13 95% UCL Calculations for Compliance with Cleanup Standards			**Sheet No.**	2 of 8

Results:

The attachments list results of the calculations and the formulae on which they are based. The results show that the samples are below direct exposure cleanup levels, and the risk associated with the carcinogenic analytes are below 10^{-5}. Both of these values are below the RAGs. Results of the DQA show that all analytes except ^{238}U satisfy the DQO requirement of 80% power; ^{238}U probably fails this test because the cleanup limit is natural background and all the samples are close to (although lower than) background.

116-B-13 KRM 7/20/99

Result Summary

~~116-B-14~~ Shallow Zone Verif Results (Statistical Values)

Am241	0.419	pCi/g
Co60	0.0418	pCi/g
Cs137	0.0657	pCi/g
Eu152	0.0981	pCi/g
Eu154	0.118	pCi/g
Eu155	0.0665	pCi/g
Pu238	0.0315	pCi/g
Pu239/40	0.0363	pCi/g
U238	(< BG)	pCi/g
Sr, rad	0.308	pCi/g
Cr+6	0.030	mg/kg
Cr	5.0	mg/kg
Hg	0.02	mg/kg
Pb	2.0	mg/kg

MTCA Evaluation

Shallow Zone:

95% UCL > Cleanup Limit?	NO	Est. Risk	7.50E-11
> 10% above Cleanup Limi	NO		
Any sample > 2X Cleanup	NO		

All power computations were >80% (error<20%).

Contents

Sheets Nos.	**Topic**
1 - 2	Summary: Explanation of problem, methodology
3	116-B-13 Shallow Zone Verif Results: Data, Statistical Parameters and Results Summary
4 - 5	116-B-13 Shallow Zone Verif Results: Formulae
6 - 7	Power Computation: Formulae
8	Power Computation

CALCULATION COVER SHEET

Project Title 116-B-13 Site Closeout **Job No.** 22192
Area 100-BC Area
Discipline Environmental ***Calc. No.** 100B-CA-N0009
Subject RESRAD Calculations Supporting Closeout of the 116-B-13 Remediation Site
Computer Program RESRAD Version 5.82 **Program No.**

Committed Calculation ☒ **Preliminary** ☐ **Superseded** ☐

Rev.	Sheet Numbers	Originator	Checker	Reviewer	Approval	Date
0	Total - 88 pages Cover/ Summary – 5 pg Attm. 1 - 1 pg Attm. 2 – 28 pg Attm. 3 – 39 pg Attm. 4 - 15 pg	W. J. McMahon W.J. McMahon 5/17/99	S. W. Clark S.W. Clark 5/17/99	K. E. Cook KEC 5/26/99	F. M. Corpuz FM Corpuz MAS 5/26/99	5/26/99

SUMMARY OF REVISION

Scanned:	Rev.	Date	Bar Code No.	Rev.	Date	Bar Code No.

*Obtain Calc. No. from DIS.

116-B-13 RESRAD CALCULATION SUMMARY

Originator:	W. J. McMahon	Date:	5/17/99	Calc. No.:	0100B-CA-N0009	Rev.:	0
Project:	116-B-13	Job No:	22192	Checked:	S. W. Clark	Date:	5/17/99
Subject:	RESRAD Calculations Supporting Closeout of the 116-B-13 Remediation Site.						

PROBLEM STATEMENT:

Calculate the soil and groundwater concentrations, dose, and risk contributions from remaining radionuclide contaminants at the 116-B-13 Remediation Site over a period of 1000 years.

GIVEN:

1) Shallow zone input data from calculation brief No. 0100B-CA-V0056, Rev. 0 "116-B-13 95% UCL Calculations for Compliance with Cleanup Standards" was input for the RESRAD runs.
2) Remedial Design Report/Remedial Action Work Plan for the 100 Area, DOE/RL-96-17, Rev. 1 (RDR/RAWP)
3) Calculation brief No. 0100B-CA-V0013, Pu-239/240 conversions.
4) For the purpose of these RESRAD calculations, the contaminants of concern are: Am-241, Co-60, Cs-137, Eu-152, Eu-154, Eu-155, Pu-238, Pu-239/240, and Sr-90. Uranium-238 was a COC for the closeout verification sampling, but it was not found at levels above site-wide background, and thus has not been carried forward through this RESRAD modeling.
5) The conservative assumption that the concentrations of contaminants found at the base of the excavation extend from the top of the backfill to groundwater at the same levels; i.e., the shallow zone represents the entire vadose zone.
6) Memo "From the Desk of" S. K. DeMers to R. C. Smith, J. G. April, and S. W. Clark, *Using RESRAD Ver. 5.61 for Chemical Data*, Dated March 5, 1997.
7) RESRAD version 5.82.

SOLUTION:

1) One RESRAD run was performed. Because the excavation did not extend to the deep zone, all verification samples were collected from only the shallow zone. For the sake of simplicity, a conservative assumption was made that the levels of contaminants detected in the shallow zone were consistent to groundwater, and that there was no backfill of clean material. Figure 1 shows the modeling assumption and the contaminant pathways considered for dose, risk, and groundwater protection.

2) The year when the peak dose (or concentration) occurred for only the drinking water pathway was determined by a preliminary run. This year was then added for the final RESRAD run. For this site, the peak dose year for all pathways is year 0, and for only the drinking water pathway the maximum year is 42.

METHODOLOGY:

1) Pu-239/240 Conversion: The relative individual Pu-239 and Pu-240 activities were calculated from the combined Pu-239/249 results reported. The calculations were performed in accordance with calculation brief No. 0100B-CA-V0013. The relative activities for Pu-239 and Pu-240 were calculated by multiplying the cleanup verification value for Pu-239/240 by 0.807 and 0.193, respectively. Table 1 shows the results from this calculation.

Table 1. Conversion of Pu-239/240 Activity to Relative Pu-239 and Pu-240 Activities

	Pu-239/240 Activity	Pu-239 (@ 0.807 multiplier)	Pu-240 (@ 0.193 multiplier)
Statistical value (pCi/g)	0.036	0.029	0.007

3) One run of RESRAD Version 5.82 was completed; the summary reports are attached. The input parameters are shown in "Part I: Mixture Sums and Single Radionuclide Guidelines," which is Attachment 2. The contaminant concentrations used for the calculations are shown in Table 2.

Table 2. Cleanup Verification Data (concentrations used for RESRAD calculations).

Radionuclides (pCi/g)	Shallow Zone (pCi/g)
^{241}Am	0.419
^{60}Co	0.042
^{137}Cs	0.066
^{152}Eu	0.098
^{154}Eu	0.118
^{155}Eu	0.066
^{238}Pu	0.032
^{239}Pu	0.029
^{240}Pu	0.007
^{90}Sr	0.308

RESULTS:

1) Radionuclide "Exposed Individual" Dose rate

The "exposed individual" dose results are shown on Table 3. The maximum dose rate, 2.14 mrem/yr, occurs at year 0 (i.e., present dose). The maximum dose rate for year 42 (this year was included in the calculation because it is the year the dose from drinking water was at a maximum) is 0.42 mrem/yr. The total dose drops to 0.03 mrem/yr in year 1,000.

Table 3. Exposed Individual COC Dose Rate (mrem/yr)

RESRAD Run #	Vadose Zone Horizons	"Exposed Individual" Dose Contributions at Each Time Slice (yr)						
		0	1	10	19	42	100	1000
1	All	2.14	2.01	1.24	0.84	0.42	0.16	0.03

2) Radionuclide Excess Cancer Risk

The radionuclide COC excess cancer risk results are shown on Table 4. The maximum risk (1.57 x 10^{-5}) occurs at year 0 (i.e., present).

Table 4. Radionuclide Excess Cancer Risk

RESRAD Run #	Vadose Zone Horizons	Excess Cancer Risk at Each Time Slice (yr)						
		0	1	10	19	42	100	1000
1	All	1.57E-05	1.48E-05	9.50E-06	6.55E-06	3.14E-06	8.84E-07	7.14E-08

3) Groundwater Protection

The RESRAD model calculated that radionuclide COC concentrations in groundwater would peak in year 42 at 0.092 pCi/L. The only COCs to reach groundwater are cobalt-60, cesium-137, and strontium-90. Table 5 shows the concentrations for each year calculated, with the peaks in bold.

Table 5. RESRAD Estimated 116-B-13 Groundwater (Drinking Water) Concentrations

Radio-nuclide	Groundwater Concentration in pCi/L at Each Time Slice (year)						
	0	1	10	19	42	100	1000
Am-241	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Co-60	0.00E+00	9.40E-05	**2.90E-04**	1.69E-04	1.81E-05	2.10E-08	0.00E+00
Cs-137	0.00E+00	1.65E-04	1.35E-03	2.08E-03	**2.70E-03**	1.68E-03	8.19E-12
Eu-152	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu-154	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Eu-155	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-238	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-240	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-90	0.00E+00	5.62E-03	4.55E-02	6.98E-02	**8.90E-02**	5.31E-02	3.39E-11

CONCLUSIONS:

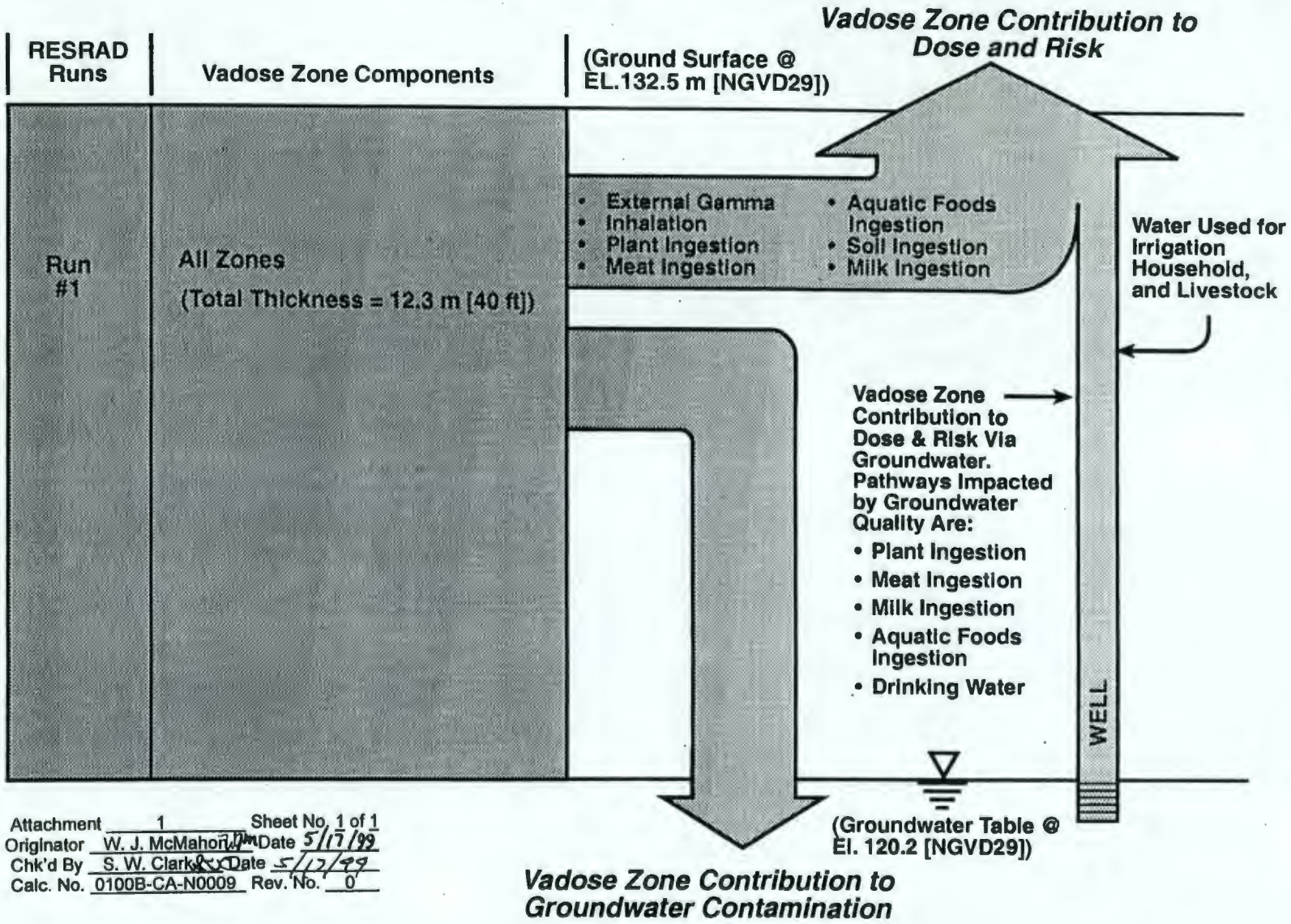
- The maximum dose rate of 2.14 mrem/yr occurs at year 0.
- The actual dose rate and risk will be significantly less because of the clean backfill.
- The dominant pathway for the dose rate is direct (ground) exposure.
- The dominant radionuclides driving the direct exposure pathway are europium-152, europium-154, and cobalt-60 at 1.37 mrem/yr in year 0. Cesium-137 exposure is about one-quarter of the magnitude of the dominant radionuclides for this pathway.
- None of the radionuclide contaminants are projected to exceed Remedial Action Goals (RAGs), even at 1,000 years.
- Excess cancer risk mirrors dose rate results; that is, the maximum excess cancer risk (1.57×10^{-5}) occurs at year 0, from the shallow zone contribution.
- The only radionuclide contaminants of concern calculated to reach groundwater are cobalt-60, cesium-137, and strontium-90. They peaked at year 42 with a maximum total concentration in groundwater of 0.092 pCi/L.

ATTACHMENTS:

1. Graphic showing 116-B-13 Cleanup Verification Model (1 page)

RESRAD Output: 116-B-13 all zones:
2. Part I: Mixture Sums and Single Radionuclide Guidelines (28 pages)
3. Part III: Intake Quantities and Health Risk Factors (39 pages)
4. Part IV: Concentration of Radionuclides (15 pages)

116-B-13 Cleanup Verification Model



Attachment 1 Sheet No. 1 of 1
Originator W. J. McMahon Date 5/17/99
Chk'd By S. W. Clark Date 5/17/99
Calc. No. 0100B-CA-N0009 Rev. No. 0

E9901101.6

Attachment 1

RESRAD INPUT PARAMETERS

1RESRAD, Version 5.82 T« Limit = 0.5 year 05/14/99 14:25 Page 1
Summary : 116-B-13 File: 1B13SZ.RAD

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1b13ssum.doc
Attachment 2 Sheet No. 1 of 28
WJM Originator W. J. McMahon Date 5/13/99
Chk'd By S. W. Clark Date 5/13/99
Calc. No. 0100B-CA-N0009 Rev. No. 0

1RESRAD, Version 5.82 T« Limit = 0.5 year 05/14/99 14:25 Page 2
Summary : 116-B-13 File: 1B13SZ.RAD

Dose Conversion Factor (and Related) Parameter Summary
File: DOSFAC.BIN

0 Menu	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ac-227+D	6.720E+00	6.720E+00	DCF2(1)
B-1	Am-241	4.440E-01	4.440E-01	DCF2(2)
B-1	Co-60	2.190E-04	2.190E-04	DCF2(3)
B-1	Cs-137+D	3.190E-05	3.190E-05	DCF2(4)
B-1	Eu-152	2.210E-04	2.210E-04	DCF2(5)
B-1	Eu-154	2.860E-04	2.860E-04	DCF2(7)
B-1	Eu-155	4.140E-05	4.140E-05	DCF2(8)
B-1	Gd-152	2.430E-01	2.430E-01	DCF2(9)
B-1	Np-237+D	5.400E-01	5.400E-01	DCF2(10)
B-1	Pa-231	1.280E+00	1.280E+00	DCF2(11)
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(12)
B-1	Pu-238	3.920E-01	3.920E-01	DCF2(13)
B-1	Pu-239	4.290E-01	4.290E-01	DCF2(14)
B-1	Pu-240	4.290E-01	4.290E-01	DCF2(15)
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(16)
B-1	Ra-228+D	5.080E-03	5.080E-03	DCF2(17)
B-1	Sr-90+D	1.310E-03	1.310E-03	DCF2(18)
B-1	Th-228+D	3.450E-01	3.450E-01	DCF2(19)
B-1	Th-229+D	2.160E+00	2.160E+00	DCF2(20)
B-1	Th-230	3.260E-01	3.260E-01	DCF2(21)
B-1	Th-232	1.640E+00	1.640E+00	DCF2(22)
B-1	U-233	1.350E-01	1.350E-01	DCF2(23)
B-1	U-234	1.320E-01	1.320E-01	DCF2(24)
B-1	U-235+D	1.230E-01	1.230E-01	DCF2(25)
B-1	U-236	1.250E-01	1.250E-01	DCF2(26)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ac-227+D	1.480E-02	1.480E-02	DCF3(1)
D-1	Am-241	3.640E-03	3.640E-03	DCF3(2)
D-1	Co-60	2.690E-05	2.690E-05	DCF3(3)
D-1	Cs-137+D	5.000E-05	5.000E-05	DCF3(4)
D-1	Eu-152	6.480E-06	6.480E-06	DCF3(5)
D-1	Eu-154	9.550E-06	9.550E-06	DCF3(7)
D-1	Eu-155	1.530E-06	1.530E-06	DCF3(8)
D-1	Gd-152	1.610E-04	1.610E-04	DCF3(9)
D-1	Np-237+D	4.440E-03	4.440E-03	DCF3(10)
D-1	Pa-231	1.060E-02	1.060E-02	DCF3(11)
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(12)
D-1	Pu-238	3.200E-03	3.200E-03	DCF3(13)
D-1	Pu-239	3.540E-03	3.540E-03	DCF3(14)
D-1	Pu-240	3.540E-03	3.540E-03	DCF3(15)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(16)
D-1	Ra-228+D	1.440E-03	1.440E-03	DCF3(17)
D-1	Sr-90+D	1.530E-04	1.530E-04	DCF3(18)
D-1	Th-228+D	8.080E-04	8.080E-04	DCF3(19)
D-1	Th-229+D	4.030E-03	4.030E-03	DCF3(20)
D-1	Th-230	5.480E-04	5.480E-04	DCF3(21)
D-1	Th-232	2.730E-03	2.730E-03	DCF3(22)
D-1	U-233	2.890E-04	2.890E-04	DCF3(23)
D-1	U-234	2.830E-04	2.830E-04	DCF3(24)

1RESRAD, Version 5.82 T« Limit = 0.5 year 05/14/99 14:25 Page 3
Summary : 116-B-13 File: 1B13SZ.RAD

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: DOSFAC.BIN

0 Menu	Parameter	Current Value	Default	Parameter Name
D-1	U-235+D	2.670E-04	2.670E-04	DCF3(25)
D-1	U-236	2.690E-04	2.690E-04	DCF3(26)
D-34	Food transfer factors:			
D-34	Ac-227+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(1,1)
D-34	Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,2)
D-34	Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF(1,3)
D-34				
D-34	Am-241 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(2,1)
D-34	Am-241 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-05	5.000E-05	RTF(2,2)
D-34	Am-241 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-06	2.000E-06	RTF(2,3)
D-34				
D-34	Co-60 , plant/soil concentration ratio, dimensionless	8.000E-02	8.000E-02	RTF(3,1)
D-34	Co-60 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-02	2.000E-02	RTF(3,2)
D-34	Co-60 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-03	2.000E-03	RTF(3,3)
D-34				
D-34	Cs-137+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(4,1)
D-34	Cs-137+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.000E-02	3.000E-02	RTF(4,2)
D-34	Cs-137+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	8.000E-03	8.000E-03	RTF(4,3)
D-34				
D-34	Eu-152 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(5,1)
D-34	Eu-152 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-03	2.000E-03	RTF(5,2)
D-34	Eu-152 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF(5,3)
D-34				
D-34	Eu-154 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(7,1)
D-34	Eu-154 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-03	2.000E-03	RTF(7,2)
D-34	Eu-154 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF(7,3)
D-34				
D-34	Eu-155 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(8,1)
D-34	Eu-155 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-03	2.000E-03	RTF(8,2)
D-34	Eu-155 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF(8,3)
D-34				
D-34	Gd-152 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(9,1)
D-34	Gd-152 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-03	2.000E-03	RTF(9,2)
D-34	Gd-152 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF(9,3)
D-34				
D-34	Np-237+D , plant/soil concentration ratio, dimensionless	2.000E-02	2.000E-02	RTF(10,1)
D-34	Np-237+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(10,2)
D-34	Np-237+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(10,3)
D-34				
D-34	Pa-231 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(11,1)
D-34	Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-03	5.000E-03	RTF(11,2)
D-34	Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(11,3)
D-34				
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(12,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(12,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(12,3)
D-34				
D-34	Pu-238 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(13,1)
D-34	Pu-238 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(13,2)
D-34	Pu-238 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-06	1.000E-06	RTF(13,3)

1b13sum.cloc
Attachment 2 Sheet No. 3 of 28
Originator W. J. McMahon Date 5/13/99
Chk'd By S. W. Clark Date 5/13/99
Calc. No. 0100B-CA-V0009 Rev. No. 0

1RESRAD, Version 5.82 T« Limit = 0.5 year 05/14/99 14:25 Page 4
Summary : 116-B-13 File: 1B13SZ.RAD

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: DOSFAC.BIN

0 Menu	Parameter	Current Value	Default	Parameter Name
D-34	Pu-239 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(14,1)
D-34	Pu-239 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(14,2)
D-34	Pu-239 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-06	1.000E-06	RTF(14,3)
D-34				
D-34	Pu-240 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(15,1)
D-34	Pu-240 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(15,2)
D-34	Pu-240 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-06	1.000E-06	RTF(15,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(16,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(16,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(16,3)
D-34				
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(17,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(17,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(17,3)
D-34				
D-34	Sr-90+D , plant/soil concentration ratio, dimensionless	3.000E-01	3.000E-01	RTF(18,1)
D-34	Sr-90+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-03	8.000E-03	RTF(18,2)
D-34	Sr-90+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-03	2.000E-03	RTF(18,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(19,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(19,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(19,3)
D-34				
D-34	Th-229+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(20,1)
D-34	Th-229+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(20,2)
D-34	Th-229+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(20,3)
D-34				
D-34	Th-230 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(21,1)
D-34	Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(21,2)
D-34	Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(21,3)
D-34				
D-34	Th-232 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(22,1)
D-34	Th-232 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(22,2)
D-34	Th-232 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(22,3)
D-34				
D-34	U-233 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(23,1)
D-34	U-233 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(23,2)
D-34	U-233 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(23,3)
D-34				
D-34	U-234 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(24,1)
D-34	U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(24,2)
D-34	U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(24,3)
D-34				
D-34	U-235+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(25,1)
D-34	U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(25,2)
D-34	U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(25,3)
D-34				
D-34	U-236 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(26,1)
D-34	U-236 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(26,2)
D-34	U-236 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(26,3)

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Attachment 2 Sheet No. 4 of 28
Originator W. . McMahon Date 5/13/99
Chk'd By [illegible] Date 5/13/99
Calc. No. 0100B-CA-N0009 Rev. No. 0

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Summary : 116-B-13 File: 1B13SZ.RAD

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: DOSFAC.BIN

0 Menu	Parameter	Current Value	Default	Parameter Name
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ac-227+D , fish	1.500E+01	1.500E+01	BIOFAC(1,1)
D-5	Ac-227+D , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(1,2)
D-5	Am-241 , fish	3.000E+01	3.000E+01	BIOFAC(2,1)
D-5	Am-241 , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(2,2)
D-5	Co-60 , fish	3.000E+02	3.000E+02	BIOFAC(3,1)
D-5	Co-60 , crustacea and mollusks	2.000E+02	2.000E+02	BIOFAC(3,2)
D-5	Cs-137+D , fish	2.000E+03	2.000E+03	BIOFAC(4,1)
D-5	Cs-137+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(4,2)
D-5	Eu-152 , fish	5.000E+01	5.000E+01	BIOFAC(5,1)
D-5	Eu-152 , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(5,2)
D-5	Eu-154 , fish	5.000E+01	5.000E+01	BIOFAC(7,1)
D-5	Eu-154 , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(7,2)
D-5	Eu-155 , fish	5.000E+01	5.000E+01	BIOFAC(8,1)
D-5	Eu-155 , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(8,2)
D-5	Gd-152 , fish	2.500E+01	2.500E+01	BIOFAC(9,1)
D-5	Gd-152 , crustacea and mollusks	1.000E+03	1.000E+03	BIOFAC(9,2)
D-5	Np-237+D , fish	3.000E+01	3.000E+01	BIOFAC(10,1)
D-5	Np-237+D , crustacea and mollusks	4.000E+02	4.000E+02	BIOFAC(10,2)
D-5	Pa-231 , fish	1.000E+01	1.000E+01	BIOFAC(11,1)
D-5	Pa-231 , crustacea and mollusks	1.100E+02	1.100E+02	BIOFAC(11,2)
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(12,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(12,2)
D-5	Pu-238 , fish	3.000E+01	3.000E+01	BIOFAC(13,1)
D-5	Pu-238 , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(13,2)
D-5	Pu-239 , fish	3.000E+01	3.000E+01	BIOFAC(14,1)
D-5	Pu-239 , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(14,2)
D-5	Pu-240 , fish	3.000E+01	3.000E+01	BIOFAC(15,1)
D-5	Pu-240 , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(15,2)
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(16,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(16,2)
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(17,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(17,2)
D-5	Sr-90+D , fish	6.000E+01	6.000E+01	BIOFAC(18,1)
D-5	Sr-90+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(18,2)

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Summary : 116-B-13 File: 1B13SZ.RAD

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
D-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(19,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(19,2)
D-5	Th-229+D , fish	1.000E+02	1.000E+02	BIOFAC(20,1)
D-5	Th-229+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(20,2)
D-5	Th-230 , fish	1.000E+02	1.000E+02	BIOFAC(21,1)
D-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(21,2)
D-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(22,1)
D-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(22,2)
D-5	U-233 , fish	1.000E+01	1.000E+01	BIOFAC(23,1)
D-5	U-233 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(23,2)
D-5	U-234 , fish	1.000E+01	1.000E+01	BIOFAC(24,1)
D-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(24,2)
D-5	U-235+D , fish	1.000E+01	1.000E+01	BIOFAC(25,1)
D-5	U-235+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(25,2)
D-5	U-236 , fish	1.000E+01	1.000E+01	BIOFAC(26,1)
D-5	U-236 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(26,2)

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Summary : 116-B-13 File: 1B13SZ.RAD

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	6.200E+02	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.230E+01	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	2.800E+01	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	4.000E+00	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	1.000E+01	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.900E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	4.200E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	1.000E+03	3.000E+02	---	T(7)
R011	Times for calculations (yr)	not used	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Am-241	4.190E-01	0.000E+00	---	S1(2)
R012	Initial principal radionuclide (pCi/g): Co-60	4.200E-02	0.000E+00	---	S1(3)
R012	Initial principal radionuclide (pCi/g): Cs-137	6.600E-02	0.000E+00	---	S1(4)
R012	Initial principal radionuclide (pCi/g): Eu-152	9.810E-02	0.000E+00	---	S1(5)
R012	Initial principal radionuclide (pCi/g): Eu-154	1.185E-01	0.000E+00	---	S1(7)
R012	Initial principal radionuclide (pCi/g): Eu-155	6.650E-02	0.000E+00	---	S1(8)
R012	Initial principal radionuclide (pCi/g): Pu-238	3.200E-02	0.000E+00	---	S1(13)
R012	Initial principal radionuclide (pCi/g): Pu-239	2.930E-02	0.000E+00	---	S1(14)
R012	Initial principal radionuclide (pCi/g): Pu-240	7.000E-03	0.000E+00	---	S1(15)
R012	Initial principal radionuclide (pCi/g): Sr-90	3.080E-01	0.000E+00	---	S1(18)
R012	Concentration in groundwater (pCi/L): Am-241	not used	0.000E+00	---	W1(2)
R012	Concentration in groundwater (pCi/L): Co-60	not used	0.000E+00	---	W1(3)
R012	Concentration in groundwater (pCi/L): Cs-137	not used	0.000E+00	---	W1(4)
R012	Concentration in groundwater (pCi/L): Eu-152	not used	0.000E+00	---	W1(5)
R012	Concentration in groundwater (pCi/L): Eu-154	not used	0.000E+00	---	W1(7)
R012	Concentration in groundwater (pCi/L): Eu-155	not used	0.000E+00	---	W1(8)
R012	Concentration in groundwater (pCi/L): Pu-238	not used	0.000E+00	---	W1(13)
R012	Concentration in groundwater (pCi/L): Pu-239	not used	0.000E+00	---	W1(14)
R012	Concentration in groundwater (pCi/L): Pu-240	not used	0.000E+00	---	W1(15)
R012	Concentration in groundwater (pCi/L): Sr-90	not used	0.000E+00	---	W1(18)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.600E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	2.500E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	2.500E+02	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	5.300E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	3.400E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	9.100E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.600E-01	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	7.600E-01	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH

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Attachment 2 Sheet No. 7 of 28
Originator W. J. McMahon Date 5/13/99
Chk'd By S. W. Clark Date 5/13/99
Calc. No. 0100B-CA-N0009 Rev. No. 0

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Summary : 116-B-13 File: 1B13SZ.RAD

Site-Specific Parameter Summary (continued)

0 Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	1.000E+06	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	Romberg failures occurred	EPS
R014	Density of saturated zone (g/cm**3)	1.600E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.500E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	5.530E+03	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	1.250E-03	2.000E-02	---	HGWT
R014	Saturated zone b parameter	5.300E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	4.600E+00	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW
R015	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	0.000E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.600E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.500E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	5.300E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	2.500E+02	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Am-241				
R016	Contaminated zone (cm**3/g)	2.000E+02	2.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+02	2.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	2.000E+02	2.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.029E-05	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R016	Distribution coefficients for Co-60				
R016	Contaminated zone (cm**3/g)	5.000E+01	1.000E+03	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	1.000E+03	---	DCNUCU(3,1)
R016	Saturated zone (cm**3/g)	5.000E+01	1.000E+03	---	DCNUCS(3)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.100E-05	ALEACH(3)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(3)
R016	Distribution coefficients for Cs-137				
R016	Contaminated zone (cm**3/g)	5.000E+01	1.000E+03	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	1.000E+03	---	DCNUCU(4,1)
R016	Saturated zone (cm**3/g)	5.000E+01	1.000E+03	---	DCNUCS(4)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.100E-05	ALEACH(4)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(4)
R016	Distribution coefficients for Eu-152				
R016	Contaminated zone (cm**3/g)	2.000E+02	-1.000E+00	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+02	-1.000E+00	---	DCNUCU(5,1)
R016	Saturated zone (cm**3/g)	2.000E+02	-1.000E+00	---	DCNUCS(5)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.029E-05	ALEACH(5)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(5)

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Summary : 116-B-13 File: 1B13SZ.RAD

Site-Specific Parameter Summary (continued)

0 Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Eu-154				
R016	Contaminated zone (cm**3/g)	2.000E+02	-1.000E+00	---	DCNUCC(7)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+02	-1.000E+00	---	DCNUCU(7,1)
R016	Saturated zone (cm**3/g)	2.000E+02	-1.000E+00	---	DCNUCS(7)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.029E-05	ALEACH(7)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(7)
R016	Distribution coefficients for Eu-155				
R016	Contaminated zone (cm**3/g)	2.000E+02	-1.000E+00	---	DCNUCC(8)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+02	-1.000E+00	---	DCNUCU(8,1)
R016	Saturated zone (cm**3/g)	2.000E+02	-1.000E+00	---	DCNUCS(8)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.029E-05	ALEACH(8)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(8)
R016	Distribution coefficients for Pu-238				
R016	Contaminated zone (cm**3/g)	2.000E+02	2.000E+03	---	DCNUCC(13)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+02	2.000E+03	---	DCNUCU(13,1)
R016	Saturated zone (cm**3/g)	2.000E+02	2.000E+03	---	DCNUCS(13)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.029E-05	ALEACH(13)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(13)
R016	Distribution coefficients for Pu-239				
R016	Contaminated zone (cm**3/g)	2.000E+02	2.000E+03	---	DCNUCC(14)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+02	2.000E+03	---	DCNUCU(14,1)
R016	Saturated zone (cm**3/g)	2.000E+02	2.000E+03	---	DCNUCS(14)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.029E-05	ALEACH(14)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(14)
R016	Distribution coefficients for Pu-240				
R016	Contaminated zone (cm**3/g)	2.000E+02	2.000E+03	---	DCNUCC(15)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+02	2.000E+03	---	DCNUCU(15,1)
R016	Saturated zone (cm**3/g)	2.000E+02	2.000E+03	---	DCNUCS(15)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.029E-05	ALEACH(15)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(15)
R016	Distribution coefficients for Sr-90				
R016	Contaminated zone (cm**3/g)	2.500E+01	3.000E+01	---	DCNUCC(18)
R016	Unsaturated zone 1 (cm**3/g)	2.500E+01	3.000E+01	---	DCNUCU(18,1)
R016	Saturated zone (cm**3/g)	2.500E+01	3.000E+01	---	DCNUCS(18)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.615E-04	ALEACH(18)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(18)
R016	Distribution coefficients for daughter Ac-227				
R016	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	2.000E+01	2.000E+01	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.017E-04	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Gd-152				
R016	Contaminated zone (cm**3/g)	-1.000E+00	-1.000E+00	8.249E+02	DCNUCC(9)
R016	Unsaturated zone 1 (cm**3/g)	-1.000E+00	-1.000E+00	8.249E+02	DCNUCU(9,1)
R016	Saturated zone (cm**3/g)	-1.000E+00	-1.000E+00	8.249E+02	DCNUCS(9)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.922E-06	ALEACH(9)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(9)
R016	Distribution coefficients for daughter Np-237				
R016	Contaminated zone (cm**3/g)	-1.000E+00	-1.000E+00	2.574E+02	DCNUCC(10)
R016	Unsaturated zone 1 (cm**3/g)	-1.000E+00	-1.000E+00	2.574E+02	DCNUCU(10,1)
R016	Saturated zone (cm**3/g)	-1.000E+00	-1.000E+00	2.574E+02	DCNUCS(10)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.577E-05	ALEACH(10)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(10)
R016	Distribution coefficients for daughter Pa-231				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(11)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(11,1)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(11)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	8.100E-05	ALEACH(11)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(11)
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	3.000E+01	1.000E+02	---	DCNUCC(12)
R016	Unsaturated zone 1 (cm**3/g)	3.000E+01	1.000E+02	---	DCNUCU(12,1)
R016	Saturated zone (cm**3/g)	3.000E+01	1.000E+02	---	DCNUCS(12)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.347E-04	ALEACH(12)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(12)
R016	Distribution coefficients for daughter Ra-226				
R016	Contaminated zone (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCC(16)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCU(16,1)
R016	Saturated zone (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCS(16)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.055E-05	ALEACH(16)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(16)
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCC(17)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCU(17,1)
R016	Saturated zone (cm**3/g)	1.000E+02	7.000E+01	---	DCNUCS(17)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	4.055E-05	ALEACH(17)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(17)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCC(19)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCU(19,1)
R016	Saturated zone (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCS(19)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.029E-05	ALEACH(19)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(19)

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Th-229				
R016	Contaminated zone (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCC(20)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCU(20,1)
R016	Saturated zone (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCS(20)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.029E-05	ALEACH(20)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(20)
R016	Distribution coefficients for daughter Th-230				
R016	Contaminated zone (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCC(21)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCU(21,1)
R016	Saturated zone (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCS(21)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.029E-05	ALEACH(21)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(21)
R016	Distribution coefficients for daughter Th-232				
R016	Contaminated zone (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCC(22)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCU(22,1)
R016	Saturated zone (cm**3/g)	2.000E+02	6.000E+04	---	DCNUCS(22)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	2.029E-05	ALEACH(22)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(22)
R016	Distribution coefficients for daughter U-233				
R016	Contaminated zone (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCC(23)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCU(23,1)
R016	Saturated zone (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCS(23)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.899E-03	ALEACH(23)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(23)
R016	Distribution coefficients for daughter U-234				
R016	Contaminated zone (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCC(24)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCU(24,1)
R016	Saturated zone (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCS(24)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.899E-03	ALEACH(24)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(24)
R016	Distribution coefficients for daughter U-235				
R016	Contaminated zone (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCC(25)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCU(25,1)
R016	Saturated zone (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCS(25)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.899E-03	ALEACH(25)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(25)
R016	Distribution coefficients for daughter U-236				
R016	Contaminated zone (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCC(26)
R016	Unsaturated zone 1 (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCU(26,1)
R016	Saturated zone (cm**3/g)	2.000E+00	5.000E+01	---	DCNUCS(26)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.899E-03	ALEACH(26)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(26)
R017	Inhalation rate (m**3/yr)	7.300E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	1.000E-04	1.000E-04	---	MLINH

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Site-Specific Parameter Summary (continued)

0 Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	8.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	6.000E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	2.000E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.000E+00	---	FRACA(3)
R017	Ring 4	not used	0.000E+00	---	FRACA(4)
R017	Ring 5	not used	0.000E+00	---	FRACA(5)
R017	Ring 6	not used	0.000E+00	---	FRACA(6)
R017	Ring 7	not used	0.000E+00	---	FRACA(7)
R017	Ring 8	not used	0.000E+00	---	FRACA(8)
R017	Ring 9	not used	0.000E+00	---	FRACA(9)
R017	Ring 10	not used	0.000E+00	---	FRACA(10)
R017	Ring 11	not used	0.000E+00	---	FRACA(11)
R017	Ring 12	not used	0.000E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	1.100E+02	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	2.700E+00	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	1.000E+02	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	3.600E+01	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	5.400E+00	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	9.000E-01	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	7.300E+02	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	1.000E+00	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	1.000E+00	5.000E-01	---	FR9
R018	Contamination fraction of plant food	-1	-1	0.310E+00	FPLANT
R018	Contamination fraction of meat	-1	-1	0.310E-01	FMEAT
R018	Contamination fraction of milk	-1	-1	0.310E-01	FMILK

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Attachment 2 Sheet No. 12 of 28
Originator W. J. McMahon Date 5/13/99
Chk'd By S. W. Clark Date 5/13/99
Calc. No. 0100B-CA-N0009 Rev. No. 0

Site-Specific Parameter Summary (continued)

0 Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	5.500E+01	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	1.600E+02	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	1.000E+00	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	1.100E+00	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	8.000E-02	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	1.000E+00	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)

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Site-Specific Parameter Summary (continued)

0 Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.000E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	active
5 -- milk ingestion	active
6 -- aquatic foods	active
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	suppressed

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      Contaminated Zone Dimensions            Initial Soil Concentrations, pCi/g
      ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ            ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
        Area:    620.00 square meters                Am-241     4.190E-01
   Thickness:     12.30 meters                       Co-60      4.200E-02
 Cover Depth:      0.00 meters                       Cs-137     6.600E-02
                                                     Eu-152     9.810E-02
                                                     Eu-154     1.185E-01
                                                     Eu-155     6.650E-02
                                                     Pu-238     3.200E-02
                                                     Pu-239     2.930E-02
                                                     Pu-240     7.000E-03
                                                     Sr-90      3.080E-01
0
                                Total Dose TDOSE(t), mrem/yr
                           Basic Radiation Dose Limit =   4 mrem/yr
        Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)
        ÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄÄ
   t (years):  0.000E+00  1.000E+00  1.000E+01  1.900E+01  4.200E+01  1.000E+02  1.000E+03
    TDOSE(t):  2.140E+00  2.012E+00  1.235E+00  8.410E-01  4.222E-01  1.627E-01  2.643E-02
        M(t):  5.351E-01  5.029E-01  3.086E-01  2.103E-01  1.055E-01  4.068E-02  6.608E-03
0Maximum TDOSE(t):  2.140E+00 mrem/yr   at t = 0.000E+00 years
```

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Attachment 2 Sheet No. 15 of 28
Originator W. J. McMahon Date 5/13/99
Chk'd By S. W. Clark Date 5/13/99
Calc. No. 0100B-CA-N0009 Rev. No. 0

CALCULATION COVER SHEET

Project Title:	100-B/C Remedial Action	**Job No.**	22192
Area	100-B Area		
Discipline	Environmental	***Calc. No.**	0100B-CA-V0041
Subject	116-B-13 Comparison to Drinking Water Standards		
Computer Program	Excel	**Program No.**	Excel 97

Committed Calculation X **Preliminary** **Superseded**

Rev.	Sheet Numbers	Originator	Checker	Reviewer	Approval	Date
0	8	D.B. Blumenkranz 5/18/99 D. B. Blumenkranz	S.W. Clark 5/18/99 S. W. Clark	J.D. Fancher 5/20/99 J. D. Fancher	F.M. Corpuz 5/26/99 F. M. Corpuz	5/26/99

SUMMARY OF REVISIONS

Scanned	Rev.	Date	Bar Code No.

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CALCULATION SHEET

Originator	D. B. Blumenkranz DBB	Date	5/18/99	Calc. No.	0100B-CA-V0041	Rev. No.	0
Project	100-B/C Remedial Action	Job No.	22192	Checked	R. W. Clark	Date	5/18/99
Subject	116-B-13 Comparison to Drinking Water Standards					Sheet No.	1 of 7

Problem:
Compare RESRAD derived groundwater radionuclide concentrations to MCLs (summarized in RDR/RAWP, DOE/RL-96-17, Rev. 1, Table 2-3). Compare alpha emitter dose contribution to the maximum allowable gross particle activity of 15 pCi/L (Safe Drinking Water Act, 40 CFR Part 141, Subpart B, 141.51). Compare beta/gamma emitter dose contribution to the maximum allowable dose of 4 mrem/yr (National Primary Drinking Water Regulations, 40 CFR Part 141, Subpart B, 141.16), as calculated using NBS Handbook 69 individual organ-dose calulation methodology and EPA-570/9-76-003 total organ-dose calulation methodology.

Given/References:
1) RESRAD derived groundwater radionuclide concentrations from Calculation 0100B-CA-N0009

2) Radionuclide concentrations in water corresponding to 4 mrem/year (C_4 mrem/yr) from Calculation 0100X-CA-V0025 or as determined from references in item 5.

3) MCLs summarized in Table 2-3 of:
DOE, 1998, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, DOE/RL-96-17, Rev. 1, U.S. Department of Engergy, Richland Operations office, Rihland, WA.

4) Maximum allowable gross particle activity (alpha emitters) and maximum allowable dose (beta/gamma emitters) from:
40 CFR 141, "National Primary Drinking Water Regulation," *Code of Federal Regulations*, as amended.

5) Individual organ-dose caclulation methodology from:
NBS 1963, *Maximum Permissible Body Burdens and Maximum Permissible Concetrations of Radionuclides in Air or Water for Occupational Exposure*, NBS Handbook 69, as amended, U.S. Department of Commerce, Washington D.C., and

EPA, *National Interim Primary Drinking Water Regulations*, EPA-570/9-76-003, U.S. Environmental Protection Agency, Office of Water Supply, Washington D.C.

Solution:
1. The site data for the calculation are the groundwater concentrations for the COCs (daughter products are not considered) over time from the RESRAD groundwater (GW) concentration file.

2. If the site conceptual model breaks the contamination into multiple layers with differing concentrations, then the GW concentrations from the various model runs are added (for each time interval) to provide the concentration data for comparison to the individual MCLs and the dose calculation for the beta and gamma emitters.

3. Compare the summed concentrations for each radionuclide to the GW MCL given in the RDR/RAWP, Table 2-3.

4. The summed concentrations for the alpha emitters (Am-241, Pu-238, Pu-239, and Pu-240) is added to see if they meet the 15 pCi/l limit specified in 40 CFR 141.15.

5. The cumulative dose for each organ for all beta and gamma emitting COCs (Co-60, Cs-137, Eu-152, Eu-154, Eu-155, Ni-63, and Sr-90) at time t is calculated separately using the corresponding to 4 mRem/year dose (C_4) and the sum of fractions equation shown below (from EPA-570/9-76-003). The organs for which doses need to be computed are total body, bone, liver and gastrointestinal tract [lower large intestine] (GI(LLI)). The individual organ doses are compared to 4 mrem/yr.

$$Dose_{organ\ x\ (t)} = [ConcA_{(t)}/C_4{}^{A}{}_{(x)} + ConcB_{(t)}/C_4{}^{B}{}_{(x)} + ...] \times (4\ mrem/yr)$$

where:
$Dose_{organ\ x\ (t)}$ is the total dose to organ x in mrem/yr
$ConcA_{(t)}$ is the concentration of isotope A at time t in pCi/L
$C_4{}^{A}{}_{(x)}$ is the 4 mrem/yr dose equivalent concentration for organ x of isotope A at time t in pCi/L
If the dose for organ x ≤ 4 mrem/yr, then the standard is met.

Conclusions:

The summed concentrations for each radionuclide are less than the GW MCL given in the RDR/RAWP.

The summed concentrations for the alpha emitting COCs are less than the 15 pCi/l limit specified in 40 CFR 141.15.

The cumulative dose for each total body, bone, liver and gastrointestinal tract for all beta and gamma emitting COCs is less than 4 mrem/yr (using EPA-570/9-76-003 total dose calculation methodology).

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Originator	D. B. Blumenkranz DBB	Date	5/18/99	Calc. No.	0100B-CA-V0041
Project	100-B/C Remedial Action	Job	22192	Checked	R. W. Stark
Subject	116-B-13 Comparison to Drinking Water Standards				

Rev. No. 0
Date 5/18/99
Sheet No. 2 of 7

Comparison of the summed concentrations for each radionuclide to the GW MCL given in the RDR/RAWP
Data derived from RESRAD modelling, units are pCi/L.

Radionuclide	Time (years)							MCL	Exceeds MCL?	Peak Conc.	Year of Peak Conc.
	0	1	10	19	42	100	1000				
Am-241	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.2	No	0.00E+00	0
Co-60	0	9.40E-05	2.90E-04	1.69E-04	1.81E-05	2.10E-08	0.00E+00	147	No	2.90E-04	10
Cs-137	0	1.65E-04	1.35E-03	2.08E-03	2.70E-03	1.68E-03	8.19E-12	120	No	2.70E-03	42
Eu-152	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	235	No	0.00E+00	0
Eu-154	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	59	No	0.00E+00	0
Eu-155	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	587	No	0.00E+00	0
Pu-238	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.6	No	0.00E+00	0
Pu-239/240	0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.2	No	0.00E+00	0
Sr-90	0	5.62E-03	4.55E-02	6.98E-02	8.90E-02	5.31E-02	3.39E-11	8	No	8.90E-02	42

CALCULATION SHEET

Originator	D. B. Blumenkranz DBB	Date	5/18/99	Calc. No. 0100B-CA-V0041	Rev. No. 0
Project	100-B/C Remedial Action	Job	22192	Checked [signature]	Date 5/18/99
Subject	116-B-13 Comparison to Drinking Water Standards				Sheet No. 3 of 7

1 Comparison of the summed concentrations for each alpha emitting radionuclide to the 15 pCi/L limit in 40 CFR 141.15.
2 Data derived from RESRAD modelling.
3

4 Radionuclide	Time (years)							Exceeds 15 pCi/L?	Peak Conc.	Year of Peak Conc.
5	0	1	10	19	42	100	1000			
6										
7 Am-241	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	No	0.000E+00	0
8 Pu-238	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	No	0.000E+00	0
9 Pu-239/240	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	No	0.000E+00	0
10										
11 Gross Alpha	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	No	0.000E+00	0

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Subject	116-B-13 Comparison to Drinking Water Standards				

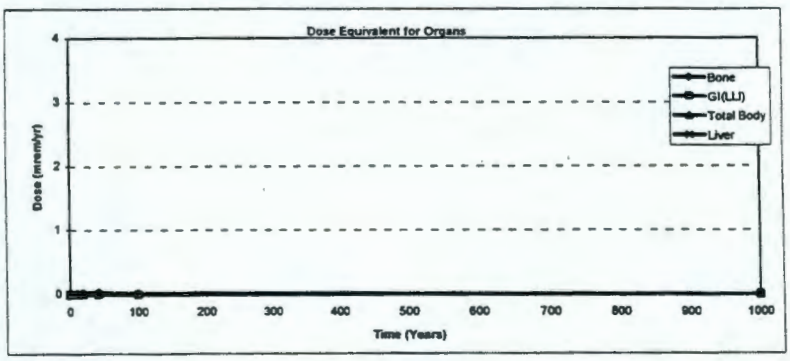
Rev. No. 0
Date 5/18/99
Sheet No. 4 of 7

1 Comparison of the summed concentrations for each radionuclide to the GW MCL given in the RDR/RAWP
2 Data derived from RESRAD modelling, units are pCi/L. C_4 values from Calculation 0100X-CA-V0025.

Radionuclide	Time (years) 0	1	10	19	42	100	1000	Organ	C_4	Exceeds 4 mrem/yr ?	Peak Conc.	Year of Peak Conc.
Co-60	0	9.400E-05	2.900E-04	1.690E-04	1.810E-05	2.100E-08	0.000E+00	GI(LLI)	100	No	2.90E-04	10
								Total Body	900	No		
								Liver	3000	No		
Cs-137	0	1.650E-04	1.350E-03	2.080E-03	2.700E-03	1.680E-03	8.190E-12	Bone	80	No	2.70E-03	42
								GI(LLI)	2000	No		
								Total Body	200	No		
								Liver	60	No		
Eu-152	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	Bone	10000000	No	0.00E+00	0
								GI(LLI)	200	No		
								Total Body	2E+08	No		
								Liver	20000000	No		
Eu-154	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	Bone	5000	No	0.00E+00	0
								GI(LLI)	60	No		
								Total Body	70000	No		
								Liver	60000	No		
Eu-155	0	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	Bone	100000	No	0.00E+00	0
								GI(LLI)	600	No		
								Total Body	900000	No		
								Liver	600000	No		
Sr-90	0	5.620E-03	4.550E-02	6.980E-02	8.900E-02	5.310E-02	3.390E-11	Bone	8	No	8.90E-02	42
								GI(LLI)	100	No		
								Total Body	8	No		

Cumulative dose for each organ (with time)

Organ	Time (years) 0	1	10	19	42	100	1000	Exceeds 4 mrem/yr?	Peak Conc.	Year of Peak
Bone	0	2.82E-03	2.28E-02	3.50E-02	4.46E-02	2.66E-02	1.74E-11	No	4.46E-02	42
GI(LLI)	0	2.29E-04	1.83E-03	2.80E-03	3.57E-03	2.13E-03	1.37E-12	No	3.57E-03	42
Total Body	0	2.81E-03	2.28E-02	3.49E-02	4.46E-02	2.66E-02	1.71E-11	No	4.46E-02	42
Liver	0	1.11E-05	9.04E-05	1.39E-04	1.80E-04	1.12E-04	5.46E-13	No	1.80E-04	42



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