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Sampling and Analysis Plan Surface Impoundments Operable Unit A and B Post-Remediation Sampling Project Oak Ridge, Tennessee

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Sampling and Analysis Plan Surface Impoundments Operable Unit A and B Post-Remediation Sampling Project Oak Ridge, Tennessee

Date Issued—June 2000

Prepared for the
U.S. Department of Energy
Office of Environmental Management

BECHTEL JACOBS COMPANY LLC
managing the
Environmental Management Activities at the
East Tennessee Technology Park
Oak Ridge Y-12 Plant Oak Ridge National Laboratory
Paducah Gaseous Diffusion Plant Portsmouth Gaseous Diffusion Plant
under contract DE-AC05-98OR22700
for the
U.S. DEPARTMENT OF ENERGY

APPROVALS AND CONCURRENCES

Sampling and Analysis Plan
Surface Impoundments Operable
Unit A and B
Post-Remediation Sampling Project
Oak Ridge, Tennessee

BJC/OR-568/R1

June 2000

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ES&H Supervisor

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ACRONYMS

AMSED	Analytical Master Specification Electronic Deliverable
APM	Analytical Project Manager
BJC	Bechtel Jacobs Company LLC
DOE	Department of Energy
DOE-ORO	Department of Energy Oak Ridge Operations Office
EPA	Environmental Protection Agency
ER	Equipment Rinsate
ERB	Equipment Rinsate Blank
H&S	Health and Safety
ICPT	Integrated Contractor Procurement Team
ORNL	Oak Ridge National Laboratory
PCB	Polychlorinated Biphenyl
PEMS	Project Environmental Measurements System
QA	Quality Assurance
QC	Quality Control
ROD	record of decision
SAP	Sampling and Analysis Plan
SIOU	Surface Impoundments Operable Unit
SMO	Sample Management Office
TVA	Tennessee Valley Authority

REVISION LOG

Revision No.	Date	Description of Changes
0	4-04-00	New Document
1	6-23-00	Incorporated comments from TDEC

1. PURPOSE

This Sampling and Analysis Plan (SAP) describes the methodology to obtain final radiological status information on the clay materials beneath the excavated sediments in the Surface Impoundments Operable Unit (SIOU) Impoundments A (3524) and B (3513), located at Oak Ridge National Laboratory (ORNL). Radiological data obtained from the representative sampling of the clay material will be used to document final conditions of the impoundments following remediation for evaluation in the Bethel Valley watershed Record of Decision (ROD). To assist in this evaluation, risk-based threshold screening values were developed. These screening values will be used to evaluate the potential risk from any residual radioactive materials still remaining after remediation. The presentation and development of the threshold screening values is presented in Appendix B of this document.

2. OBJECTIVES

The objective of this SAP is to describe the procedure for obtaining sufficient and valid analytical data on clay materials to evaluate the post-remedial status before filling and covering the impoundments. Additionally, screening data will be obtained to rapidly evaluate radiological status, including information for subsequent packaging and shipment of samples to off-site laboratory facilities.

3. SCOPE

This plan provides supplemental instructions to guidelines and procedures established for sampling and analysis activities. Standard procedures may be referenced throughout this plan as applicable, and are available for review if necessary.

4. ORGANIZATION AND RESPONSIBILITIES

Overall coordination and implementation of the activities described in this plan are the responsibility of the Bechtel Jacobs Company LLC (BJC) Project Manager, or his/her designee. The BJC Project Manager will require input and support from personnel of NFT, Inc. and MDM Services Corporation, as well as various BJC and subcontractor organizations. The roles and responsibilities of these personnel are listed in Table 1.

Table 1. Roles and responsibilities

Role	Person	Phone	Responsibility
BJC Project Manager	Charles Mansfield	576-1777	BJC project management
MDM, Inc	Mark Selecman		Oversee and obtain samples from the impoundments
NFT, Inc. Analytical Project Manager	Beth Mitchell	241-9127 X223	Oversees sampling and analysis activities, interfaces with project managers
Safety Advocate	Jim Craven	574-9472	Provides health and safety oversight and assists in sampling activities, ensures proper training and documentation and access to the work area
SMO	Kelli Henry	241-1176	Ensures the requirements of the SAP are met by the laboratories and provides customer interface
SEC Radiological Control	To be determined		Provides radiological control support

5. SAMPLE DESCRIPTION

The clay identified for evaluation is related to the base of the impoundments (liner materials, floor, sub-impoundment, etc.), and is currently contained on the bottom of SIOU Impoundments A and B. The impoundments were used as part of the system for management of low-level radioactive wastes generated from experiments and material processing at ORNL. The impoundments currently contain contaminated sediment that includes organic materials such as leaves, small twigs, and decomposed organic materials. Once the sediment and approximately 0.1 foot of clay have been removed, the remaining surface (presumably clay) will be sampled to a depth of 6 inches or at sampler refusal.

6. SAMPLING

6.1 NOTIFICATION

The Project Manager will notify the sampling and analytical organizations before sampling activities begin. This notification is needed to allow the NFT Analytical Project Manager (APM) time to schedule programmatic activities. The NFT APM shall notify laboratory analysis personnel regarding the time and date of sampling operations, if necessary.

6.2 PRE-SAMPLING MEETING

The Project Manager will schedule and conduct a pre-sampling meeting with project personnel before sampling operations. The objectives of this meeting will be to discuss sampling operation logistics and other details, resolve any technical or operational issues, and ensure schedules are agreed upon by all responsible organizations. The Project Manager will also verify training records pertinent to this project are complete and available for inspection.

6.3 SAMPLING OPERATIONS

The Project Manager will ensure sampling activities adhere to the SAP and the Health and Safety Plan, and applicable procedures. **Sampling shall not be initiated before receipt of a signed copy of the SAP.** Signed copies of the SAP will be distributed before the initiation of sampling activities.

6.3.1 Logbook Entries

The MDM field project manager (or designee) will maintain a logbook to provide project information and a daily written record of all sampling activities. The logbook will be maintained in accordance with MDM Services Corporation procedure MDM-TP-8023, Rev. 2, *Notebooks.* Project information should include personnel contacts, training activities, and site data. Each daily logbook entry should include, but is not limited to, the following items:

- general activities,
- weather conditions,
- end-of-day status, and
- problems.

6.3.2 Sampling Collection Overview

Sampling activities will require collection of three types of analytical samples. The samples will consist of composite, biased, and field quality control (QC) samples. Sampling will involve intrusive and systematic methods. Samples will be collected in accordance with the following procedures, as applicable:

- *Environmental Protection Agency Region IV Standard Operating Procedures,* Section 12 – Soil Sampling, 1997.
- *Collection of Soil Samples,* ESP-301-1.
- *Collection of Sediment Samples,* BJC, ES-B-0901, Rev. 0.
- *Sampling of Sediment, Sludge, Soil,* BJC, ES-B-0901, Rev. 0.

Location samples will be collected and contained in appropriate sample containers (specified in Table 2). Initial samples will be collected to a depth of 6 inches at each location, and at 6-inch intervals thereafter if the risk-based threshold values are exceeded (Appendix B).

Seven composite samples are planned to be collected from SIOU A. SIOU B is expected to have nine composite samples. Each composite sample will consist of three to nine sample points collected from each systematic composite sample grid. The sample locations will be selected using the grid system provided in Appendix A, using the coordinate system on Tennessee Valley Authority (TVA) map S-16A. The number of samples collected should represent the media of each impoundment. Attachment A details the sample locations and composite strategy. At the direction of the BJC Project Manager, the number of samples may be altered based on changing project goals and/or analytical data as it becomes available. Changes to this plan shall be documented in the logbook and project files.

Specific equipment for taking samples may include stainless collection devices (Shelby tubes, stainless steel trays, coring devices, etc.), a low-volume pump and related equipment for removing excess liquid from the sample locations, and a modified stainless steel drum for creating a seal and containing the sediment/sludge in the selected sample location. Other supplies and equipment will include standard sample bottles, sample handling tools such as stainless steel scoops and spatulas, and radiological contamination control supplies. Any deviations from this method will be approved by BJC project management, and/or the Sample Management Office. Equipment that is fabricated and designed on-site must meet the requirements for analytical standards and support the needs of the sampling team. The equipment should be designed with decontamination processes in mind, and should be fabricated from materials meeting analysis criteria.

Table 2. Sample containers

Analytical methods	Container type	Preservative	Sample volumes
Alpha Spectroscopy	Glass, with Teflon-lined lid	None	100 g
Alpha Spectroscopy			100 g
Alpha Spectroscopy			100 g
Gamma Spectroscopy			100 g
Gamma Spectroscopy			100 g
Beta GPC			100 g
Gross Alpha/Beta			50 g

6.3.3 Sample Collection Methodology

All materials necessary for sample collection will be staged, cleaned, and inspected before sampling. At this time, an Equipment Rinsate Blank (ERB) sample will be collected for the deionized water, and an Equipment Rinsate (ER) sample will be collected on all reusable sampling equipment (see Table 3 for field QC requirements). The selected sampling locations will then be accessed using the existing floating platform that is located at the impoundments.

Following collection, the location of each sample will be logged in the field logbook. Samples will be collected using a stainless steel coring tool inserted into the clay. At this time, the assumption will be that the tool has contacted the clay liner. The sampling team will continue the insertion until approximately 6 inches of clay is contained in the tool or until refusal. The team will then remove the tool from the impoundment clay.

The sampled materials will be removed from the coring tool using a stainless steel spatula and placed into a stainless steel holding tray. Field radiological measurements will be recorded at this time using handheld survey instruments. The clay sample will be retained and homogenized with other individual sample points from the systematic composite grid. Stainless steel tools and spatulas will be used to homogenize the materials. When initial homogenization is completed, the composite materials will be transferred to the sample container. (**Note: Simple field decontamination measures may be necessary to ensure contamination controls. If deemed necessary by the sampling team, or Radiation Protection personnel, sampling equipment may be rinsed during sampling activities using deionized water**).

The methods described above will be repeated until all samples have been collected and placed into the sample containers. Any excess impoundment water will be removed before homogenization of the sample. Free standing water should be removed from the sample homogenization. The homogenized sample will be packaged and prepared for laboratory delivery using the information contained in Table 2 of this SAP, quality assurance (QA) requirements, and standard radiological protection procedures. All tools, equipment, and containers used for a sample shall be cleaned/decontaminated and rinsed before reuse (see Section 6.3.5).

6.3.4 Field QC Samples

When required by EPA standards, and when specified by the BJC Project Manager, Field QC samples will be collected during the sampling activities. QC samples will be collected in accordance with this SAP and applicable procedures. Sampling shall be consistent with EPA's *Test Methods for Evaluating Solid Waste,* SW-846, Third Edition. Preservation of equipment rinsate blanks (ERBs) and field duplicates shall adhere to the methods described in this SAP. Field duplicates will be collected for a selected sample from each impoundment. The BJC Project Manager will specify the time and location of the collection of the duplicate sample.

Table 3. Requirements for field QC samples

Sample type	Analytes	Analytical methods	Container type	Preservative	Sample volume
Field Duplicate	Same as Table 2	Same as Table 2	Same as Table 2	Same as Table 2	Same as Table 2
Equipment Rinsate Blank and Equipment Rinsate	**Radionuclides:** Gross Alpha/Beta	Gross Alpha/Beta	1 liter, amber with Teflon-lined lid	pH <2 with HNO_3	1 liter

6.3.5 Sampling Equipment Decontamination

Nondisposable sampling equipment shall be decontaminated and documented in accordance with *Cleaning and Decontaminating Sample Containers and Sampling Devices,* ESP-801. If required, procedure ESP-802, *Equipment Decontamination,* will be used for larger equipment.

6.3.6 Sampling Identification

Samples will be identified using the following identification coding and qualifiers.

6.3.7 Identification Numbering

Project Code(s):SIOU3524 = SIOU 3524 Designation (SIOU A)
SIOU3513 = SIOU 3513 Designation (SIOU B)

Qualifiers:
Clay random sample designation = S#
Field Duplicate Designation = DUP
Equipment Rinsate Blank Designation = ERB
Equipment Rinsate Designation = ER
Clay composite sample designation = C#

Examples:
Clay Sample (random): SIOU3524S1 = SIOU 3524 Sample #1
Clay Sample (composite): SIOU3513C2 = SIOU 3513 Composite #2
Clay Sample (random dup): SIOU3542S7DUP = SIOU 3542 Sample #7 duplicate

Field QC Samples: SIOU3524ER2 = SIOU 3524 Equipment Rinsate Sample #2
SIOUERB1 = SIOU Project Equipment Rinsate Blank Sample #1

6.3.8 Sample Labels

Sample labeling will be conducted in accordance with this SAP. Appropriate sample labels (e.g., Analytical, polychlorinated biphenyls [PCBs], Radioactive) will be affixed to all sample containers before or at the time of sampling. To the extent practicable, sample bottles will be labeled before filling. Sample labels will be waterproof paper or plastic with gummed backs or waterproof tags, as appropriate. Labels will be completed with black indelible ink or Project Environmental Measurements System (PEMS) pre-printed labels will be used. At a minimum, the following information will be included on sample labels:

- sample name
- unique customer sample number (**Note: Do not hyphenate customer sample numbers.**)
- sampler's name
- date and time of collection
- location of collection
- analyte
- preserved/non-preserved (indicate type of preservative)

6.3.9 Sample Chain of Custody

The integrity of a sample from the time of sampling through receipt into the laboratory is assured by strict adherence to MDM Services Corporation procedure MDM-TP-8055, Rev. 3, *Chain of Custody*. Copies of the completed chain-of-custody forms shall be provided to the BJC Project Manager and NFT APM upon completion of sampling activities, or after direct delivery to the laboratory. The following information, as a minimum, must be included on the chain-of-custody forms:

- unique sample number;
- signature of sample collector;
- date and time of collection;
- sample matrix type (i.e., sludge, soil, etc);
- sample site;
- number of containers;
- sample handling and preservatives;
- date and time custody is accepted and relinquished;
- signature of each custodian; and
- sampling and analysis requested.

6.3.10 Custody Seals

Custody seals assure that unauthorized additions to a container's contents can be visually detected. The custody seal shall be placed in a manner such that opening the container breaks the seal. A custody seal shall be placed on the following containers:

- containers that were sampled;
- analytical samples not delivered to the laboratory within 24 hours of sampling or not stored in a secure storage facility; and
- storage and transport packages such as ice coolers, etc.

6.3.11 Sample Management

The condition of samples (e.g., temperature, presence of custody seals, hazard labels, samples shipped on ice, etc.) shall be checked and documented by laboratory personnel upon arrival at the laboratory. Samples shall be stored and preserved according to the QA procedures of the analytical laboratory.

6.3.12 Risk-Based Screening Analysis

Once a sample has been collected and removed into the staging area, it will be split into various individual containers based on the analysis to be performed. The screening analysis will be performed for gross beta, gross alpha, total strontium, and gamma spectroscopy for target radionuclides (strontium-90, cesium-137, cobalt-60 and americum-241), and will be available within 72 hours. This "forms only" type of screening is to rapidly compare the results to the risk-based threshold values in Table ES.2 of Appendix B. This will also provide sufficient information to ship/transport the composite samples off site. The minimum detectable activity for each analysis will be 10 pCi/g (dry weight basis). In addition to risk-based screening analysis on each discrete sample, the composite samples will be screened for rapid turn-around time.

Screening results for these radionuclides will be compared to the risk-based threshold screening values in Table ES.2 of Appendix B, *Determination of Threshold Screening Values for Post-Remedial Activities of Surface Impoundments Operable Unit A and B at the Oak Ridge National Laboratory, Oak Ridge, Tennessee.* Gamma spectroscopy results for Am-241, Co-60 and Cs-137 will be directly compared to the risk-based threshold values in Table ES.2. Total strontium results will be assumed to be Sr-90 and will be compared to the Sr-90 risk-based threshold screening value in Table ES.2 of Appendix B.

Appendix B describes the method to compare the residual radiological contamination in the subimpoundment soils to the threshold screening values. The presentation and development of the threshold screening values is presented in Table ES.1 and Table ES.2 in Appendix B of this document.

To evaluate the residual contamination across each impoundment, the concentration of each target radiological isotope will be averaged across all samples. This representative concentration will be determined by calculating the 95^{th} percentile upper confidence limit on the mean (UCL95). Because it is possible for the UCL95 to be greater than the maximum detected value, the lesser of the maximum and the UCL95 will be used as the representative concentration, if this occurs. If all the threshold screening values for the target radiological isotopes are not exceeded, then the FFA parties will be notified and agree that the impoundment will be backfilled. If any of the threshold screening values are exceeded, then the FFA parties will be notified and each individual sample will be compared to the threshold screening values for the target radiological isotopes that exceeded the threshold screening values. By doing this, it is possible to focus on areas in the subimpoundment soils that may require further remediation.

In the event that the site representative concentration of the target radiological isotopes exceeds its threshold screening value, the FFA parties will be notified and further investigation and/or remediation may be required. Things to evaluate would be:

1. half-life of the contaminant that exceeded the threshold screening value. If the contaminant that exceeds the threshold screening value has a short half-life, the site may be backfilled.
2. source term potential of the amount of contamination remaining. If the volume of contamination remaining is considered to be too small to be a continual source of downgradient contamination,

the site may be backfilled. Also, if the contaminant present that still exceeds the threshold screening value is not easily transported in environmental media, the site may be backfilled.

3. likelihood of exposure. The threshold screening values were developed to be protective of a future uncontrolled excavation worker. It is unlikely that, in the near future, uncontrolled excavation will occur in the impoundments. Also, when the site is backfilled, the fill material will provide a barrier of protection to the industrial worker. This is accomplished because it is considered that the industrial worker is only exposed to the first 2 feet of soil. The depth to the former bottom of the impoundments, once excavated and backfilled, will exceed 10 feet.

4. further risk and transport analysis. If the threshold screening values are exceeded, they will be further evaluated in the Bethel Valley watershed ROD.

6.3.13 Composite Samples and Analyses

Composite samples will be sent to an off-site Sample Management Office (SMO)-procured laboratory and analyzed for radionuclides listed in Table 4. Data Deliverables for composite samples shall include all QA/QC results and raw instrument data. Composite samples and discrete sample locations are shown in Appendix A, Figure 1.

Table 4. Requirements for SIOU composite samples

Analyte	Analytical methods	Container type	Preservative	Sample volumes
Radionuclides[a]		Glass, with Teflon-lined lid	None	
Isotopic-Pu[b]	Alpha Spectroscopy			100 g
Isotopic-U	Alpha Spectroscopy			100 g
Americium-241[b]	Alpha Spectroscopy			100 g
Cesium-137[b]	Gamma Spectroscopy[c]			100 g
Cobalt-60[b]	Gamma Spectroscopy[c]			100 g
Strontium-90[b]	Beta GPC			100 g
Gross Alpha/Beta	Gross Alpha/Beta			50 g

[a] Report results in picocuries/gram, dry weight.

[b] Specifically listed in the Record of Decision, Table 2.1. Source: *Record of Decision for the Surface Impoundments Operable Unit, Oak Ridge National Laboratory*, DOE/OR/02-1630&D2, September 1997.

[c] Other gamma emitters that are identified shall be quantified and reported.

6.3.14 Sample Transportation

All samples will be transported in accordance with requirements that will ensure compliance with DOT regulations in 49CFR173. Samples will be packaged and transported in accordance with NFT, Inc. procedure NFT-PEL-022, *Transportation and Shipping of Samples*, dated January 12, 2000. Records/calculations for determining if samples meet the definition of "limit quantities" will be maintained in the project files. BJC transportation personnel will be contacted if samples exceed the limited quantity value. Samples will be sealed in plastic bags and packaged in coolers. Each cooler will have absorbent material added as a precaution, and packing material to prevent sample movement and breakage.

7. ANALYTICAL REQUIREMENTS

The laboratory procured by the Sample Management Office will ensure that all analyses are performed in accordance with this SAP, and all QC is performed in accordance with SW-846 and *Integrated Contractor Procurement Team (ICPT) Radiological Analytical Master Specification,* dated September 1998. Any deviations from specified methods or parameters must be approved and documented by the NFT APM or his/her designee before making changes. The laboratory shall:

- archive all samples for 60 days;
- notify the NFT APM immediately of any QC failures that would require resampling;
- report data on a dry weight basis unless otherwise specified;
- representatively obtain subsamples for analysis, rather than attempting to select the "cleanest" or "dirtiest" portion of the sample; and
- supply Level 3 package for analysis data.

8. QUALITY ASSURANCE (QA) REQUIREMENTS

Any exceptions or deviations to this plan require authorization from the BJC Project Manager and Department of Energy (DOE) Program Manager. Sample collection procedures may be "red-lined" during activities to reflect actual sample collection methods used by the sampling team. The "red-line" instances will be documented in the project field logbook and must be approved by the BJC Project Manager.

Authorizations for deviations to procedures and this SAP can be made via telephone, verbal communications, or written instructions. When authorization is other than written correspondence, the BJC Project Manager shall document the date, requestor's name, and the deviation or exception. Deviations from analytical activities shall be approved by the NFT APM before implementation and must be documented in project records.

BJC Quality Assurance personnel may conduct surveillances during sampling operations. Requirements such as chain-of-custody, sample labels, tamper-proof seals, field logbook entries, and the collection of QC samples will be reviewed for compliance to the procedures mentioned in this SAP. Surveillance reports and any corrective action documentation will become part of the program's QA records. QA and other relevant project documentation will be maintained for a minimum of three years.

The NFT APM will ensure that analytical data obtained complies with applicable analytical methods, the *Integrated Contractor Procurement Team (ICPT) Radiological Analytical Master Specification,* dated September 1998, and this SAP.

9. DATA DELIVERABLES

The data deliverables for this project will be Level 3, and will include results, QC Summary Forms, and all raw instrument data. The NFT APM will ensure that analytical data is reported to the appropriate project personnel. All analytical results will be provided as they become available. Complete data packages will be provided within 30 days of the initial analytical results.

Electronic data shall be provided by the analytical laboratory in the Analytical Master Specification Electronic Deliverable (AMSED) format. Results shall be transmitted by the laboratory to the PEMS database via the Internet.

10. DATA REVIEW AND VALIDATION

Ten percent of the data packages generated for this project will be validated according to BJC procedure ES-A-2209, *Radiochemical Data Verification and Validation*, dated March 3, 1999. If there are no major quality control concerns, no further validation will be required. If major quality control concerns are found, validation of all analytical data packages will be required. A validation report will be prepared by NFT, Inc. and provided to the BJC Project Manager.

11. HEALTH AND SAFETY (H&S)

Health and Safety (H&S) support will be obtained from site H&S organizations. Preliminary reviews (e.g., Site Safety Reviews, Radiation Work Permits, etc.), requests for H&S services, and establishment of communication with H&S organizations are addressed in the Activity Hazards Analysis. The Safety Advocate is given in Table 1. No additional hazards other than those addressed in the original plan are anticipated.

12. REFERENCES

Environmental Protection Agency Region IV Standard Operating Procedures, Section 12 – Soil Sampling, Environmental Protection Agency, 1997.

Test Methods for Evaluating Solid Waste, SW-846, Third Edition. Environmental Protection Agency, November 1986.

Cleaning and Decontaminating Sample Containers and Sampling Devices, ESP-801, Revision 0, Martin Marietta Energy Systems, August 27, 1988.

Integrated Contractor Procurement Team (ICPT) Radiological Analytical Master Specification, September 2, 1998.

Radiochemical Data Verification and Validation, ES-A-2209, Bechtel Jacobs Company, LLC, March 3, 1999.

Record of Decision for the Surface Impoundments Operable Unit, Oak Ridge National Laboratory, DOE/OR/02-1630&D2, September 1997.

Collection of Soil Samples, ESP-301-1.

Collection of Sediment Samples, ES-B-0901, Rev. 0, Bechtel Jacobs Company, LLC.

Sampling of Sediment, Sludge, and Soil, ES-A-0900, Bechtel Jacobs Company, LLC.

Notebooks, MDM-TP-8023, Rev. 2, MDM Services Corporation.

Chain of Custody, MDM-TP-8055, Rev. 3, MDM Services Corporation.

Cleaning and Decontaminating Sample Containers and Sampling Devices, ESP-801.

Equipment Decontamination, ESP-802.

APPENDIX A

BASIS FOR NUMBER AND LOCATIONS OF SAMPLING POINTS

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BASIS FOR NUMBER AND LOCATIONS OF SAMPLING POINTS

The objective of collecting the samples will be to detect areas of elevated concentrations of contaminants and determine the radiological profile of the cleaned bottom surfaces. The area extent of sampling in SIOU A and B is defined by the 780' and 775' contour lines, respectively. A practical approach to accomplish these objectives is to sample on a 20' grid and generate composite samples using generally 6 to 9 samples per composite. Each sample will be radiologically screened before being added to the composite, and a portion of each individual sample will be archived for subsequent analysis, if necessary. Only the composite samples will be sent for off-site analysis. Based on screening individual samples from each 20' grid point, the probability of "hitting" an elevated area of contamination can be estimated. Table 1 lists the probability for hitting various circular sized areas. Figure 1 shows the sampling locations and compositing strategy.

Table A-1. 20-in. grid spacing for locating circular spots

Radius (ft)	Circular area (ft^2)	Probability of hitting (%)
2	13	<3
5	79	20
10	314	78
12	707	>95

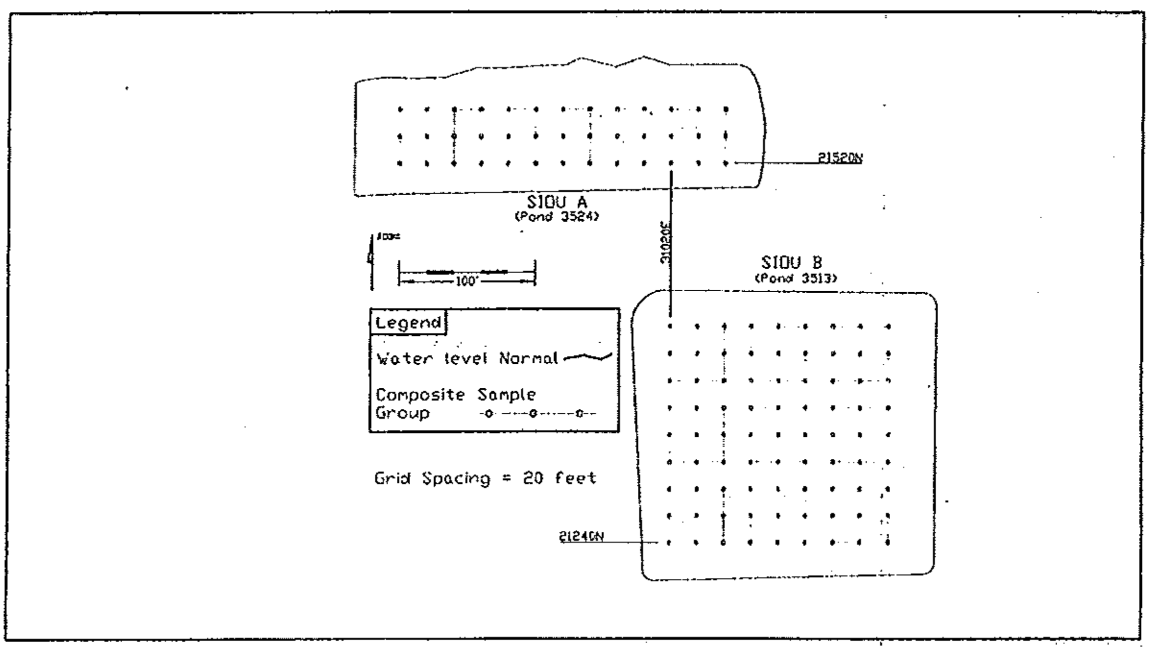

Fig. A-1. Sampling locations for SIOU A and B.

APPENDIX B

RISK ASSESSMENT SUPPORT

Determination of Threshold Screening Values for Post-Remediation Activities at Surface Impoundments Operable Unit A and B at the Oak Ridge National Laboratory, Oak Ridge, Tennessee

The University of Tennessee, Knoxville
Center for Information Studies, Environmental Applications Group

contributed to the preparation of this document and should not be considered an eligible contractor for its review.

Determination of Threshold Screening Values for Post-Remediation Activities at Surface Impoundments Operable Unit A and B at the Oak Ridge National Laboratory, Oak Ridge, Tennessee

Date Issued—March 2000

Prepared by
The University of Tennessee
Knoxville, Tennessee
Center for Information Studies, Environmental Applications Group
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Prepared for the
U.S. Department of Energy
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ABBREVIATIONS

ATRANS	analytical solute transport model
BJC	Bechtel Jacobs Company LLC
BRA	Baseline Risk Assessment
COC	chemical of concern
COPC	chemical of potential concern
DOE	U.S. Department of Energy
EDE	effective dose equivalent
EPA	U.S. Environmental Protection Agency
FTWORK	groundwater flow model (developed by Lockheed Martin)
g	gram
HEAST	Health Effects Assessment Summary Tables (EPA's)
L	liter
MCL	maximum contaminant level
mrem	millirem (radiation dose equivalent)
ORNL	Oak Ridge National Laboratory
OSWER	Office of Solid Waste and Emergency Response (EPA)
pCi	picoCuries
RAGS	Risk Assessment Guidance for Superfund (EPA)
RAIS	Risk Assessment Information System (UT/ORNL)
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SF	slope factor (excess lifetime cancer risk)
SIOU	Surface Impoundments Operable Unit
UT	The University of Tennessee
WOC	White Oak Creek

EXECUTIVE SUMMARY

Impoundments A (3524) and B (3513)[1] of the Oak Ridge National Laboratory (ORNL) Surface Impoundment Operable Unit (SIOU) will be remediated to the requirements stated in the ROD (DOE 1997a). The ROD is specific in the extent of remediation, namely all sediments and 0.03 m (0.1 ft) of subimpoundment soils. It does not provide threshold screening values to determine if potential residual contamination may need to be addressed as a post-remediation action prior to backfilling the impoundments or prior to investigation as part of the Bethel Valley Watershed project.

The analysis provided in this report presents additional information (threshold screening values) that may assist field personnel and project managers in determining if potential residual contamination in the subimpoundment soils should be removed prior to backfilling the impoundments. The threshold screening values selected are based on protection of human health and are risk-based values that are specific for a potential future excavation worker. In addition, the threshold screening values are only specific for the SIOU and should not be applied to any other site without proper exposure assessment. The estimation of risk-based threshold screening values was based on two previous analyses, *Characterization of Potential Radiation Dose and Risk Following Remediation of the ORNL Surface Impoundments Operable Unit* (DOE 1998) and *Evaluation of Potential Impact of Residual Contamination in Impoundment 3513 at the Oak Ridge National Laboratory, Oak Ridge, Tennessee* (Jacobs 1998), with minor modifications of the base assumptions and exposure scenarios.

Two hypothetical exposure scenarios were used in this analysis to select threshold screening values:

- direct contact with contaminated subimpoundment soil by a hypothetical future excavation worker, and
- indirect exposure to the contaminants in the subimpoundment soils by a hypothetical future off-site resident via contaminant leaching into the groundwater and subsequent migration underneath the impoundments into the surface waters of the White Oak Creek (WOC).

Both scenarios do not reflect the current use patterns of the ORNL SIOU area, but are conservative estimates of reasonable maximum exposure scenarios that assume the Department of Energy (DOE) no longer has institutional control of the ORNL SIOU area. After comparing the hypothetical exposure scenarios, the "direct contact with contaminated subimpoundment soil by a hypothetical future excavation worker" was selected as the threshold screening value. The hypothetical excavation worker results were more conservative values when compared to the modeled values for transport to surface water.

The threshold screening values of the hypothetical future excavation worker scenario are shown in Table ES.1. These values were generated on The University of Tennessee/ORNL Risk Assessment Information System (RAIS; http://risk.lsd.ornl.gov/rap_hp.shtml). The U.S. Environmental Protection Agency Region IV and the DOE-Oak Ridge Operations Office have approved use of the RAIS for generating screening values based on ORO-standardized exposure scenarios. The values in Table ES.1 are based on ingestion, external exposure, and inhalation of contaminated soil. This equates to a "total" exposure scenario.

[1] Note that previous documents are inconsistent in the use of the numerical designations assigned to Impoundments A and B. Throughout this report, uniform designations are maintained by correcting document titles or other referenced material.

Table ES.1. Risk-based threshold screening values for hypothetical future excavation scenario – total exposure

Radionuclide	Threshold (pCi/g)[a]	Threshold (pCi/g)[b]
^{241}Am	3.1E+04	3.1E+02
^{60}Co	7.0E+02	7.0E+00
^{137}Cs+D	3.2E+03	3.2E+01
^{238}Pu	3.5E+04	3.5E+02
^{239}Pu	3.3E+04	3.3E+02
^{240}Pu	3.3E+04	3.3E+02
^{90}Sr+D	1.9E+05	1.9E+03

[a] For risk = 1E-4.
[b] For risk = 1E-6.

Because of the shallow depth of groundwater at the impoundments, it is likely that the future hypothetical excavation worker would encounter groundwater. As addressed in the uncertainty section of this report, it is very likely that the soils will be saturated with water, if not entirely under water. Because of this, it is highly unlikely that there will be any dry soil available for inhalation of particulates. Further, the amount of water present would provide shielding from external radiation. Table ES.2 presents the threshold screening values for the hypothetical future excavation worker scenario for ingestion only.

Table ES.2. Risk-based threshold screening values for hypothetical future excavation scenario – ingestion only

Radionuclide	Threshold (pCi/g)[a]	Threshold (pCi/g)[b]
^{241}Am	3.2E+04	3.2E+02
^{60}Co	5.5E+05	5.5E+03
^{137}Cs+D	3.3E+05	3.3E+03
^{238}Pu	3.5E+04	3.5E+02
^{239}Pu	3.3E+04	3.3E+02
^{240}Pu	3.3E+04	3.3E+02
^{90}Sr+D	1.9E+05	1.9E+03

[a] For risk = 1E-4.
[b] For risk = 1E-6.

It is recommended that the threshold screening values in Table ES.1 are used if there is no water present in the impoundments. It is highly likely, however, that water will be present. When water is present, it is recommended that the threshold screening values in Table ES.2 are used. The threshold screening values in Tables ES.1 and ES.2 are not actionable levels for this site. Further, they are in no way to be considered as threshold screening values that are applicable to the Bethel Valley Watershed ROD Project. Instead, the threshold screening values presented in this report are a tool for the project team to evaluate the levels of contamination left in the subimpoundment soils. If the threshold screening values are exceeded, further remedial action may not be required; however, it may be necessary to reevaluate the efficiency of the remediation.

1. BACKGROUND

The document, *Post-Remediation Radiological Evaluation Work Plan for the Stage 2 Remedial Action on the Surface Impoundments Operable Unit A and B at the Oak Ridge National Laboratory, Oak Ridge, Tennessee*, BJC/OR-454 (BJC 1999), presents the following background information:

> Impoundments A (3524) and B (3513) of the Surface Impoundments Operable Unit (SIOU) at the Oak Ridge National Laboratory (ORNL) will be remediated to the requirements stated in the Record of Decision (ROD), DOE/OR/02-1630&D2 (DOE 1997a). This remedy addresses the principal threats to industrial workers and mitigates the release of contamination to the groundwater by (1) removal of the sediment from the SIOU and (2) transport of all treated waste to an approved disposal facility. The ROD includes the following: (1) removal of impoundment sediments and approximately 0.03 m (0.1 ft) of subimpoundment soil within the SIOU, (2) discharge of surface water to the existing Process Waste Treatment Plant; (3) treatment of sediments to meet applicable or relevant and appropriate requirements and disposal facility waste acceptance criteria, (4) containerization of the treated waste, and (5) transport of the treated waste to an approved waste disposal facility and disposal therein.
>
> The subimpoundment soil area extends from the bottom of the impoundment down to bedrock. The average subimpoundment soil thickness is 2.5 ft for Impoundment A and 3 ft for Impoundment B; however, the subimpoundment soil on the east end of Impoundment A may be up to 8 ft thick (Ketelle 1999).
>
> Fate and transport modeling conducted as part of the SIOU Remedial Investigation/Feasibility Study (RI/FS) (DOE 1995) was performed to simulate the risk from release of radionuclides and chemicals from the SIOU into the environment. Results of the baseline risk assessment performed for the SIOU in the RI/FS indicated that the on-site future risk to employees or residents exceeded the U.S. Environmental Protection Agency target risk range for cancer (10^{-6} to 10^{-4}) when radionuclides such as ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, ^{60}Co, ^{90}Sr, or ^{137}Cs in the soil or sediment are exposed. According to the RI/FS, "The pathways contributing the majority of the risk are direct radiation, inhalation of airborne particulates, and incidental ingestion of soil and sediment." The potential mobilization of ^{90}Sr from the sediment to groundwater and ultimately to surface waters of White Oak Creek was predicted to be the primary off-site exposure pathway in the event that these surface waters are used by a hypothetical future receptor as a drinking water source.
>
> Risk modeling per formed during the RI/FS indicated that if nonradioactive chemical risks were the only consideration, the associated risk from the chemicals present would not necessitate a remedial action.

2. PREVIOUS RISK ASSESSMENT RESULTS

The following sections describe the previous risk assessment results and methods to obtain residual risk values for the subimpoundment soils at the Oak Ridge National Laboratory (ORNL) Surface Impoundments Operable Unit (SIOU) during post-remediation conditions.

This section summarizes the previous risk assessment results from the following three documents: *Remedial Investigation/Feasibility Study for Surface Impoundments Operable Unit, Waste Area Grouping 1, Oak Ridge National Laboratory, Oak Ridge, Tennessee,* DOE/OR/02-1346&D2; *Characterization of Potential Radiation Dose and Risk Following Remediation of the ORNL Surface Impoundments Operable Unit (SIOU),* DOE Order 980401.0033; and *Evaluation of Potential Impact of Residual Contamination in Impoundment 3513 at the Oak Ridge National Laboratory, Oak Ridge, Tennessee,* JE/EM-59.

2.1 RISK RESULTS OF THE RI/FS

As part of the RI/FS, a baseline risk assessment (BRA) was performed on contamination in the surface waters and sediment of the SIOU. This BRA showed risks for current and future on-site employees or hypothetical future residents exceeding the target risk range for cancer, primarily when the radionuclides in the sediments are exposed (loss of water shielding).

In addition, the contamination in sediments is known to slowly migrate via groundwater to surface water into White Oak Creek (WOC) and contribute to the risks, albeit not predominantly, to hypothetical off-site receptors using the surface waters of WOC.

For the current on-site land use, the BRA of the RI/FS assumed an industrial worker under institutional control receiving an unacceptable dose if the water shielding of the impoundments were to be removed. If the sediments were to dry up as well and become airborne, the inhalation of alpha-emitting radionuclides (including plutonium and americium) would greatly increase the risk of lung cancer over a widespread area.

Hypothetical future off-site residents would also have unacceptable risks from radioactive contaminants if institutional controls were lost. Again, the main risk is inhalation of windblown particulates derived from the sediments, but also risk contributions from radionuclide releases into the groundwater and subsequent release into the WOC surface waters are present.

The risk results of the RI/FS provided information necessary for DOE to propose and sign into action the preferred alternative in the ROD to remove the sediments and surface waters of the impoundments. Therefore, upon the implementation of the remediation, the exposure pathways of external exposure and inhalation of contaminated particulates will no longer be completed pathways.

The RI/FS and Record of Decision (ROD) for the SIOU do not specifically address legacy risks from leaving in place the subimpoundment soils underneath the fill material. The risk information available in the RI/FS and the ROD does not provide risk-based threshold screening values for radionuclides potentially remaining in the subimpoundment soils.

2.2 RISK RESULTS FROM *CHARACTERIZATION OF POTENTIAL RADIATION DOSE AND RISK FOLLOWING REMEDIATION OF THE ORNL SURFACE IMPOUNDMENTS OPERABLE UNIT*

This report (DOE 1998) presents the risk results of residual contamination of radionuclides in the subimpoundment soils of the SIOU.

An excavation scenario that allowed intrusion through the clean fill material into the subimpoundment soils was used to estimate exposure to hypothetical future industrial worker receptors not under the Department of Energy (DOE) institutional control. The scenario assumption was that a pipeline or utility trench would be dug traversing the impoundments 300 years into the future and that the hypothetical unrestricted-access excavator worker would be exposed to the unearthed subimpoundment soils for one work week (40 hours, 5 working days).

Two approaches were used to estimate the exposure point concentration. One approach is based on volume-weighted average subimpoundment soil concentrations underneath all four impoundments of the SIOU; the other approach is based on modeled results of semi-quantitative derivation of subimpoundment soils underneath Impoundment B (3513). Both concentration terms were then modeled for decay into the future for 300 years and diluted by mixing subimpoundment soil with clean fill material in the bucket of a backhoe used to excavate the subimpoundment soils.

Figure 1 shows a stem-and-leaf conceptual site model that represents the hypothetical exposure scenario described in *Characterization of Potential Radiation Dose and Risk Following Remediation of the ORNL Surface Impoundments Operable Unit* (DOE 1998).

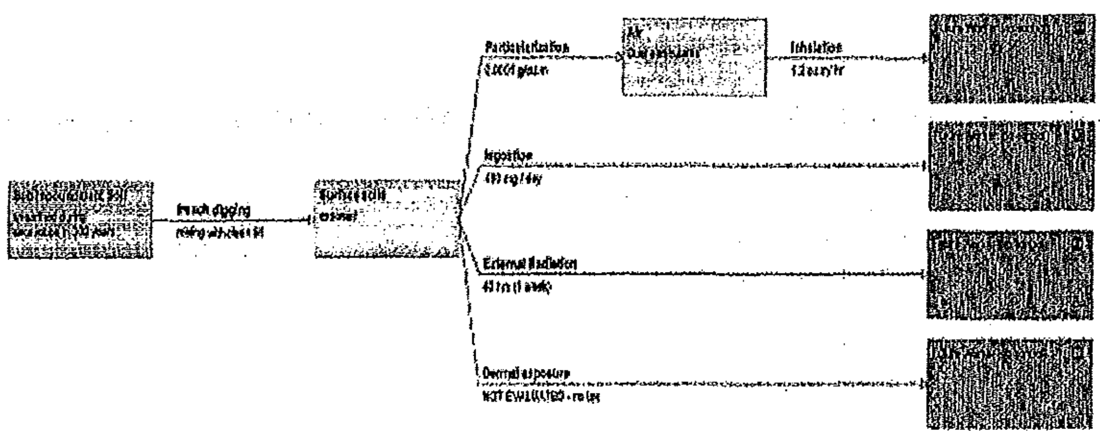

Fig. 1. Conceptual site model of previous risk result for excavation scenario.

The report's results showed that subsequent to remediation of the SIOU sediments, the subimpoundment soils are unlikely to require further action from a risk-based perspective. More specifically, the estimated concentrations of the current subimpoundment soil contamination will not exceed a risk-based threshold when excavated in 300 years.

2.3 RISK RESULTS FROM *EVALUATION OF POTENTIAL IMPACT OF RESIDUAL CONTAMINATION IN IMPOUNDMENT 3513 AT THE OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE*

This report (Jacobs 1998) presents the surface water concentration results of leaching and transport in groundwater of residual contamination of radionuclides in the subimpoundment soils of the SIOU.

Previous modeling performed during the RI/FS indicated that of the four impoundments in the SIOU, Impoundment B (3513) is the most significant contributor of ^{90}Sr contamination and risk to WOC.

To evaluate the potential effects of residual contamination, the analyses used a hypothetical layer of 15 cm (6 in.) of subimpoundment soils contaminated with ^{90}Sr at concentrations equivalent to those of the sediments. The associated physical/chemical parameters of the subimpoundment soils required to model the release and migration of ^{90}Sr were also conservatively estimated using sediment properties.

Three mathematical groundwater models were linked and used to predict ^{90}Sr concentrations in WOC. The RI/FS provided site-specific calibration of a groundwater flow model (FTWORK), which was again used in the analysis. Leaching of ^{90}Sr into the groundwater was modeled with a source release model using sediment characteristics as proxies for the characteristics of the subimpoundment soils. Finally, an analytical solute transport model (ATRANS) was used to simulate ^{90}Sr transport in the groundwater from the SIOU into WOC.

Results of the predictive modeling showed that the maximum concentration of ^{90}Sr activity in WOC resulting from releases of the hypothetical 15-cm (6-in.) layer of contaminated subimpoundment soil would occur 142 years in the future. The value of this maximum activity is 8 x 10^{-3} pCi/L at WOC adjacent to the SIOU. Figure 2 (Jacobs 1998) shows the results of the predicted ^{90}Sr concentration in WOC.

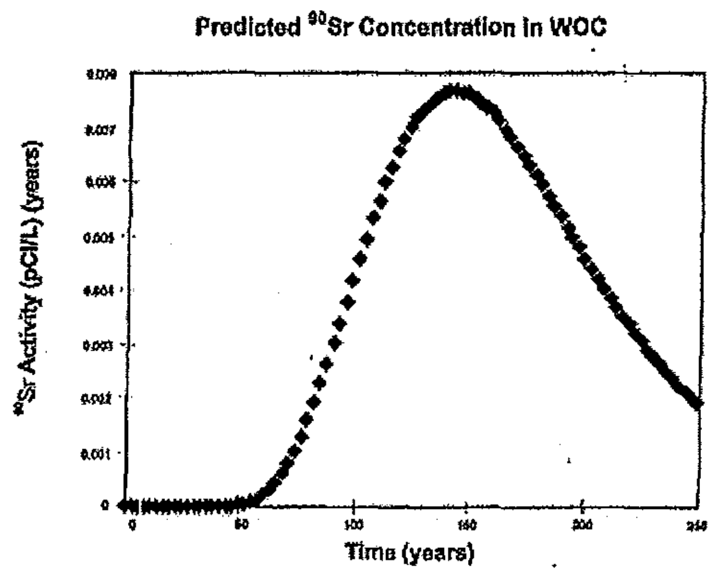

Fig. 2. Predicted ^{90}Sr concentration in WOC.

Fig. 2. Predicted ^{90}Sr concentration in WOC.

3. DETERMENATION OF THRESHOLD SCREENING VALUES

The following sections present the method used to obtain threshold screening values for radionuclides in the subimpoundment soils for the ORNL SIOU during post-remediation conditions that are protective of human health.

The U.S. Environmental Protection Agency (EPA) Region IV has approved use of The University of Tennessee/ORNL Risk Assessment Information System (RAIS; DOE 2000) for Department of Energy – Oak Ridge (DOE-OR) sites. The URL for the RAIS is http://risk.lsd.ornl.gov/rap_hp.shtml. Using the regulatory-approved DOE-OR standardized exposure scenarios, risk-based threshold screening values were obtained for radionuclides in the subimpoundment soils at the SIOU.

3.1 CHEMICALS OF POTENTIAL CONCERN DETERMINATION

Previous RI/FS and associated documents on the SIOU provide extensive information on the history, physical setting, surroundings, chemical and radionuclide constituents, and other descriptive characteristics of the impoundments. For the purposes of this assessment, only the identity of the chemicals of potential concern (COPCs) in the subimpoundment soils and the processes by which future receptors may be exposed to these COPCs are relevant.

The risk-driving contaminants, or chemicals of concern (COCs), identified in the RI/FS are radionuclides present in the sediment and surface waters of the SIOU. The radionuclides are ^{238}Pu, ^{233}Pu, ^{240} Pu, ^{241}Am, ^{60}Co, ^{90}Sr, and ^{137}Cs. The COPCs for the subimpoundment soils are believed to be the same as the COCs of the sediment and surface waters. It is possible, but very unlikely, that the subimpoundment soils contain COPCs that were not identified as COCs in the sediment and surface waters.

3.2 EXPOSURE SCENARIOS AND CONCEPTUAL SITE MODEL

In accordance with the previous report (*Characterization of Potential Radiation Dose and Risk Following Remediation of the ORNL Surface Impoundments Operable Unit*, DOE 1998), a hypothetical industrial excavation worker scenario was chosen to represent the most likely (and after implementation of remediation – the ONLY scenario) to be exposed directly to the contaminants in the subimpoundment soils.

Indirect exposure to the contaminants in the subimpoundment soils can occur when the contaminants in the subimpoundment soils are released and leach into the groundwater. The groundwater then migrates underneath the impoundments and empties into the surface waters of WOC as visible seeps on the banks and through direct communication with the streambed. Use of groundwater is not currently allowed. Because of general water quality concerns of this shallow aquifer, future use is not believed to be probable. Contact with surface waters of WOC is believed to be the most likely and significant indirect exposure pathway for the hypothetical future off-site resident receptor. Results for site-specific fate and transport modeling of subimpoundment soil contamination are shown in the report *Evaluation of Potential Impact of Residual Contamination in Impoundment 3513 at the Oak Ridge National Laboratory, Oak Ridge, Tennessee* (Jacobs 1998), which used ^{90}Sr to evaluate the fate and transport modeling for contaminants in the subimpoundment soils of Impoundment B (3513). In the RI/FS, ^{90}Sr was identified as a COC for the sediments and surface waters and contributed the largest risks for the indirect exposure pathway mentioned above.

Figure 3 shows the stem-and-leaf conceptual site model diagram for the excavation scenario and the indirect exposure pathways.

3.3 CALCULATION OF THRESHOLD SCREENING VALUES FOR EXCAVATION SCENARIO

To calculate a threshold screening value protective of human health, the exposure routes of inhalation, dermal contact, incidental ingestion, and external radiation were evaluated. The threshold screening values are risk based. The dermal contact pathway was not quantified because of a lack of appropriate toxicity factors for radionuclides and because the external radiation pathway is already being quantified. All other exposure routes were quantified.

To determine the concentration of a chemical that will result in a specified target risk level, the individual risk equations must be rearranged to solve for the concentration term and combined to reflect the additivity of risks across the exposure routes. The individual dose equations are shown below.

3.3.1 Inhalation of Soil Particulates in Dust

$$\text{Intake dose (pCi)} = CS \times ED \times CF \times EF \times HR \times (VF^{-1} + PEF^{-1})$$

where the DOE-OR standardized excavation worker scenario uses the following assumptions:

- CS = Risk-based threshold concentration in subimpoundment soil to be determined (pCi/g).
- ED = Exposure duration. Value is 1 year [Office of Solid Waste and Emergency Response (OSWER) Directive (EPA 1991b); the intrusion into subimpoundment soils will occur only once in a worker's lifetime].
- CF = Conversion factor. Value is 10^3 g/kg [necessary to convert to appropriate unit].
- EF = Exposure frequency. Value is 20 days/year [based on 1 work month for building a basement or similar structure].
- HR = Inhalation rate. Value is 20 m^3/day [OSWER Directive (EPA 1991b); based on medium work load breathing rates].
- VF = Volatilization factor. Value is chemical-specific (m^3/kg) [for the radionuclide COPCs at the ORNL SIOU, none have appreciable volatilization].
- PEF = Particulate emission factor. Value is 1.32×10^9 m^3/kg [climate-specific value adjusted for site-specific conditions based on the *Soil Screening Guidance: User's Guide* (EPA 1996)].

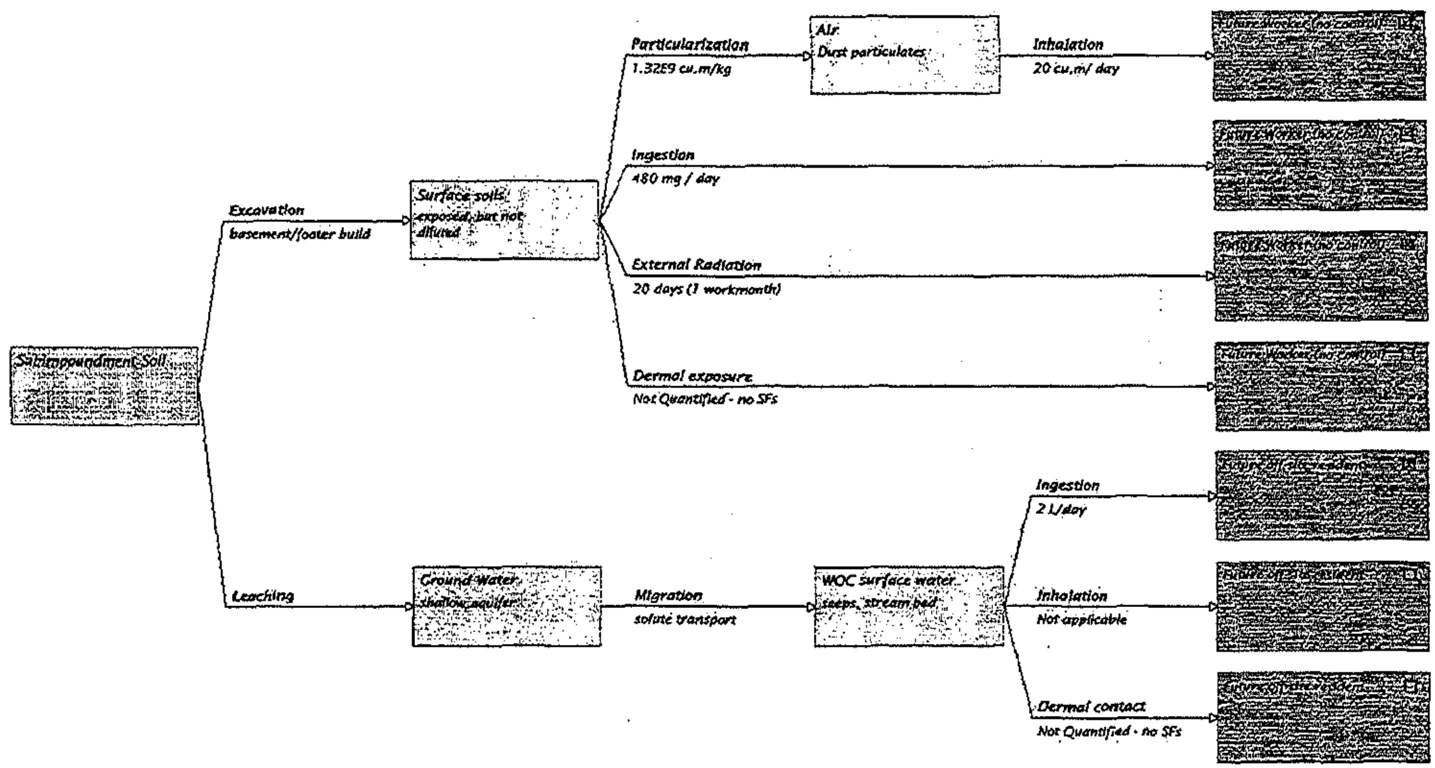

Fig. 3. Conceptual site model for residual contamination in SIOU subimpoundment soils.

3.3.2 Incidental Ingestion of Soil

$$\text{Intake dose (pCi)} = CS \times CF \times EF \times ED \times IR$$

where the DOE-OR standardized excavation worker scenario uses the following assumptions:

CS = Risk-based threshold concentration in subimpoundment soil to be determined (pCi/g).
ED = Exposure duration. Value is 1 year [OSWER Directive (EPA 1991b); the intrusion into subimpoundment soils will occur only once in a worker's lifetime].
CF = Conversion factor. Value is 10^3 g/kg [necessary to convert to appropriate unit].
EF = Exposure frequency. Value is 20 days/year [based on 1 work month for building a basement or similar structure].
IR = Ingestion rate. Value is 0.00048 kg/day (usually shown as 480 mg/day) [Risk Assessment Guidance for Superfund (RAGS), Part B (EPA 1991a); based on incidental hand-to-mouth and soil-to-food transfer].

3.3.3 External Radiation

$$\text{Dose (pCi – year/g)} = CS \times (1 - Se) \times Te \times ED \times EF \times CF$$

where the DOE-OR standardized excavation worker scenario uses the following assumptions:

CS = Risk-based threshold concentration in subimpoundment soil to be determined (pCi/g).
Se = Gamma shielding factor. Value is 0.2 (unitless) [RAGS, Part B (EPA 1991a); based on a default, planar source geometry].
Te = Gamma exposure time factor. Value is 8/24 hours/hour (unitless) [(EPA 1991a); based on an 8-hour workday in a 24-hour day].
ED = Exposure duration. Value is 1 year [OSWER Directive (EPA 1991b); the intrusion into subimpoundment soils will occur only once in a worker's lifetime].
CF = Conversion factor. Value is (1/365) year/days [necessary to convert to appropriate unit].
EF = Exposure frequency. Value is 20 days/year [based on 1 work month for building a basement or similar structure].

3.3.4 Combined, Rearranged Equation

Combining and rearranging the equations to solve for the subimpoundment soil concentration at a specified excess individual lifetime cancer risk level yields the following equation:

$$C = \frac{TR}{ED \times [(SF_o \times CF \times EF \times IR \times FI) + (SF_x \times EF_x \times (1 - S_e) \times T_e) + (SF_i \times CF \times EF \times (1/VF + 1/PEF) \times HR)]}$$

where the DOE-OR standardized excavation worker scenario uses the following assumptions:

C	=	Risk-based threshold concentration in subimpoundment soil to be determined (pCi/g).
TR	=	Target excess individual lifetime cancer risk value. Value is set to either 1E-4 risk level or 1E-6 risk level.
ED	=	Exposure duration. Value is 1 year [OSWER Directive (EPA 1991b); the intrusion into subimpoundment soils will occur only once in a worker's lifetime].
SF_o	=	Slope factor for ingestion (oral). Value is chemical-specific [EPA Health Effects Assessment Summary Tables (HEAST) database].
CF	=	Conversion factor. Value is 10^3 g/kg [necessary to convert to appropriate unit].
EF	=	Exposure frequency. Value is 20 days/year [based on 1 work month for building a basement or similar structure].
IR	=	Ingestion rate. Value is 0.00048 kg/day (usually shown as 480 mg/day) [RAGS, Part B (EPA 1991a); based on incidental hand-to-mouth and soil-to-food transfer].
FI	=	Fraction ingested. Value is 1 (unitless) [the entire day's incidental ingestion is assumed to come from the subimpoundment soils].
SF_x	=	Slope factor for external radiation. Value is chemical-specific [EPA HEAST database].
EF_x	=	Exposure frequency (for external exposure). Assumed to be equal to EF since the worker is not believed to reside on-site.
Se	=	Gamma shielding factor. Value is 0.2 (unitless) [RAGS, Part B (EPA 1991a); based on a default, planar source geometry].
Te	=	Gamma exposure time factor. Value is 8/24 hr/hr (unitless) [(EPA 1991a); based on an 8-hour workday in a 24-hour day].
SF_i	=	Slope factor for inhalation. Value is chemical-specific [EPA HEAST database].
VF	=	Volatilization factor. Value is chemical-specific (m^3/kg) [for the radionuclide COPCs at the ORNL SIOU, none have appreciable volatilization].
PEF	=	Particulate emission factor. Value is 1.32×10^9 m^3/kg [climate-specific value adjusted for site-specific conditions based on *Soil Screening Guidance: User's Guide* (EPA 1996)].
HR	=	Inhalation rate. Value is 20 m^3/day [OSWER Directive (EPA 1991b); based on medium work load breathing rates].

3.3.5 Toxicity Factors

Radionuclide-specific toxicity factors, specifically carcinogenic endpoint slope factor values, were obtained from the RAIS collection of EPA's HEAST database (EPA 1995). These values are current as of February 2000 and reflect the most recent changes to the EPA dose conversion factors approach used to derive the slope factors (Table 1).

Table 1. Radionuclide toxicity slope factor values

Radionuclide	Half-life (days)	SF_i (risk/pCi)	SF_o (risk/pCi)	SF_x (risk/year/pCi/g)
^{241}Am	1.58E+05	3.85E-08	3.28E-10	4.59E-09
^{60}Co	1.92E+03	6.88E-11	1.89E-11	9.76E-06
^{137}Cs+D	1.10E+04	1.91E-11	3.16E-11	2.09E-06
^{238}Pu	3.20E+04	2.74E-08	2.95E-10	1.94E-11
^{239}Pu	8.80E+06	2.78E-08	3.16E-10	1.26E-11
^{240}Pu	2.40E+06	2.78E-08	3.15E-10	1.87E-11
^{90}Sr+D	1.04E+04	6.93E-11	5.59E-11	0.00E+00

3.3.6 Risk-based Threshold Screening Values

Using the combined, rearranged equation and the identified parameters and toxicity values, the risk-based threshold screening values for subimpoundment soils were determined. The risk-based threshold screening values in pCi/g for the COPC radionuclides are shown in Table 2.

Table 2. Risk-based threshold screening values for hypothetical future excavation scenario

Radionuclide	Threshold (pCi/g)[a]	Threshold (pCi/g)[b]
^{241}Am	3.1E+04	3.1E+02
^{60}Co	7.0E+02	7.0E+00
^{137}Cs+D	3.2E+03	3.2E+01
^{238}Pu	3.5E+04	3.5E+02
^{239}Pu	3.3E+04	3.3E+02
^{240}Pu	3.3E+04	3.3E+02
^{90}Sr+D	1.9E+05	1.9E+03

[a] For risk = 1E-4.
[b] For risk = 1E-6.

3.4 CALCULATION OF THRESHOLD SCREENING VALUES FOR INDIRECT EXPOSURE SCENARIO

In addition to the direct exposure pathways evaluated in the previous section, an indirect exposure pathway may result from potential releases of radionuclide contamination in the subimpoundment soils to groundwater and subsequent release to surface waters of WOC.

The previous report *Evaluation of Potential Impact of Residual Contamination in Impoundment 3513 at the Oak Ridge National Laboratory, Oak Ridge, Tennessee* (Jacobs 1998) predicted that the maximum ^{90}Sr concentration in WOC will occur in 142 years and have a maximum activity of 8×10^{-3} pCi/L.

The value of 8×10^{-3} pCi/L is three orders of magnitude below the federal and state drinking water concentration limit of 8 pCi/L for ^{90}Sr [the concentration limit is not a maximum contaminant limit (MCL), but is based on a concentration that results in the effective dose equivalent (EDE) of 4 mrem/year, the MCL for gross beta emissions]. The concentration limit and explanation were obtained from the RAIS.

A hypothetical future off-site resident using the surface waters of the WOC was chosen as a reasonable maximum exposure scenario receptor to be exposed to the risks from ^{90}Sr releases from subimpoundment soils. As shown in Fig. 3, the hypothetical future off-site resident may be exposed to risks from ^{90}Sr in the WOC surface waters through ingestion, inhalation, and dermal contact. Of these exposure routes, dermal contact cannot be quantified because a dermal toxicity value or carcinogenic slope factor is not available, and inhalation is not applicable because ^{90}Sr does not volatilize. Therefore, only the ingestion exposure route is quantified.

The dose equation for ingestion of water-borne contaminants is shown below:

$$\text{Intake dose (pCi)} = C \times IR \times EF \times ED$$

where,

C = Concentration of radionuclide in water (pCi/L).
IR = Ingestion rate. Value is 2 L/day [RAGS, Part B (EPA 1991a)].
EF = Exposure frequency. Value is 350 days/year [RAGS, Part B (EPA 1991a)].
ED = Exposure duration. Value is 30 years [RAGS, Part B (EPA 1991a)].

Rearranging this equation and combining it with the carcinogenic slope factor for ^{90}Sr ingestion of 5.59E-11 [risk/pCi] yields the risk-based concentration in water that will result in a specified excess individual lifetime cancer-risk level, as shown in the following equation:

$$C = \frac{TR}{SF_o \times IR \times EF \times ED}$$

where,

C = Risk-based threshold concentration in WOC surface water to be determined (pCi/L).
TR = Target excess individual lifetime cancer risk value. Value is set to either 1E-4 risk level or 1E-6 risk level.
SF_o = Slope factor for ingestion (oral). Value is chemical-specific [EPA HEAST database].
IR = Ingestion rate. Value is 2 L/day [RAGS, Part B (EPA 1991a)].
EF = Exposure frequency. Value is 350 days/year [RAGS, Part B (EPA 1991a)].
ED = Exposure duration. Value is 30 years [RAGS, Part B (EPA 1991a)].

The risk-based threshold screening values of ^{90}Sr in WOC surface waters are 8.5E+01 pCi/L for a target risk level of 1E-4 and 8.5E-01 pCi/L for a target risk level of 1E-6. The lower of the two values is a conservative estimate and is almost one order of magnitude below the federal and state drinking water concentration limit of 8 pCi/L.

To determine the subimpoundment soil threshold screening value, the risk-based threshold screening values of ^{90}Sr in WOC surface waters would have to be "run backwards" through the groundwater modeling strategy described in the previous report, *Evaluation of Potential Impact of Residual Contamination in Impoundment 3513 at the Oak Ridge National Laboratory, Oak Ridge, Tennessee* (Jacobs 1998). However, this is not practical or possible for the analytical solutions of the three groundwater models. Instead, a linear ratio approach is used to estimate the concentration of ^{90}Sr in subimpoundment soil that would result in a WOC surface water concentration of 8.5E+01 pCi/L and 8.5E-01 pCi/L for target risk levels of 1E-4 and 1E-6, respectively. The ratio approach uses the modeled ^{90}Sr concentrations in the surface waters of WOC over the concentrations in the hypothetical subimpoundment soil layer assumed in the modeling. This approach sets this ratio equal to the ratio of risk-based threshold concentration of ^{90}Sr in WOC surface water over the risk-based threshold concentration of ^{90}Sr in the subimpoundment soil layer. This equation is shown as follows:

$$\frac{{}^{\text{Model}}[{}^{90}\text{Sr}]_{\text{WOC water}}}{{}^{\text{Model}}[{}^{90}\text{Sr}]_{\text{Sub soil}}} = \frac{{}^{\text{Risk threshold}}[{}^{90}\text{Sr}]_{\text{WOC water}}}{{}^{\text{Risk threshold}}[{}^{90}\text{Sr}]_{\text{Sub soil}}}$$

Rearranging the equation to solve for the risk-based threshold value of ^{90}Sr in subimpoundment soil yields:

$${}^{\text{Risk threshold}}[{}^{90}\text{Sr}]_{\text{Sub soil}} = {}^{\text{Risk threshold}}[{}^{90}\text{Sr}]_{\text{WOC water}} \times \frac{{}^{\text{Model}}[{}^{90}\text{Sr}]_{\text{Sub soil}}}{{}^{\text{Model}}[{}^{90}\text{Sr}]_{\text{WOC water}}}$$

The linear ratio approach should yield reasonable results, because the groundwater flow model outputs should not be affected by the changed ^{90}Sr concentration, the source release model has a linear source to release concentration relationship, and the site-specific characteristics of the analytical solute transport model are unchanged.

The ^{90}Sr concentration in subimpoundment soil used in the modeling was based on the 95th percentile upper confidence limit on the mean for the ^{90}Sr concentration in sediment as a conservative estimate. The value of ^{90}Sr concentration in the sediment of Impoundment B (3513) given in the RI/FS report is 140,000 pCi/g dry weight. Using the modeled WOC surface water concentration for ^{90}Sr of 8E-3 pCi/L and the risk-based threshold WOC surface water concentrations of 8.5E+01 pCi/L and 8.5E-01 pCi/L for target risk levels of 1E-4 and 1E-6, respectively, the values shown in Table 3 are obtained.

Table 3. Risk-based threshold screening values for indirect exposure scenario

Target risk level	Risk-based threshold screening values for subimpoundment soil (pCi/g dry)
1E-4	1.5E+9
1E-6	1.5E+7

Clearly, these values are four orders of magnitude higher than the proposed risk-based threshold screening values for subimpoundment soils estimated for the excavation scenario. Therefore, the lower values of the excavation scenario are recommended as the risk-based threshold screening values for radionuclides in the subimpoundment soils.

4. UNCERTAINTY

Uncertainties in the estimation of the threshold screening values for the potential radionuclide contamination remaining after remedial action at the ORNL SIOU are numerous. This section discusses the uncertainties of the hypothetical scenario selection, the uncertainties of the subimpoundment soil characteristics, and the uncertainties in the threshold value calculations.

4.1 SCENARIO SELECTION

Two hypothetical exposure scenarios are used in this analysis: a hypothetical future excavation worker scenario and a hypothetical future off-site resident. Both scenarios do not reflect the current use patterns of the ORNL SIOU area, but are conservative estimates of reasonable maximum exposure scenarios that may occur sometime in the future when DOE no longer has institutional control of the ORNL SIOU area. For the foreseeable future, however, DOE is believed to maintain institutional control of ORNL and the types of exposures estimated here will not occur.

The hypothetical future excavation worker scenario is premised on the assumption that no personal protective equipment is deployed and that the excavation of a footer or basement for a building will intrude vertically through the clean fill material of the impoundments into the subimpoundment soil layers. Because the subimpoundment soil layer is immediately above the groundwater table, excavation for a construction site will most likely stop before reaching the subimpoundment soil layer and, thus, not expose hypothetical future excavation workers to the possible residual contamination.

Another uncertainty in this analysis is the assumption that the subimpoundment soils are not diluted through mixing with the clean fill material as excavation is occurring. This is a highly conservative assumption and the previous report, *Characterization of Potential Radiation Dose and Risk Following Remediation of the ORNL Surface Impoundments Operable Unit* (DOE 1998) assumed a 0.1 ft subimpoundment soil layer being mixed in a 1.5 ft backhoe scoop volume. The previous analysis assumed a piping or utility trench construction and not a footer or basement construction. A mixing dilution for a trench construction scenario may be more reasonable than for the larger area excavation scenario presented here. Also, the contact duration for a trench construction is assumed to be only 1 work week (5 days), while the footer or basement construction will require 1 work month (20 days). The latter should be a conservative estimate of the reasonable maximum exposure duration to unearthed subimpoundment soils.

Once unearthed, the subimpoundment soils are assumed to behave equivalent to surface soils. Minimal or no vegetative cover is assumed and standard climate conditions for the southeastern region (Climate Group VI) are used (EPA 1996). These assumptions are probably highly conservative since the subimpoundment soils are believed to be partially or fully saturated with groundwater and both the particularization and subsequent inhalation of dust-borne contamination and the external radiation pathways are minimized or eliminated if the subimpoundment soils are saturated. Table 4 presents a quantitative evaluation of this uncertainty by calculating the threshold screening value for the ingestion exposure route only. If during excavation activities it is found that groundwater has saturated the subimpoundment soils, it is recommended that the threshold screening values presented in Table 4 be used rather than the threshold screening values in Table 2.

Table 4. Risk-based threshold screening values for hypothetical future excavation scenario – ingestion only

Radionuclide	Threshold (pCi/g)[a]	Threshold (pCi/g)[b]
^{241}Am	3.2E+04	3.2E+02
^{60}Co	5.5E+05	5.5E+03
^{137}Cs+D	3.3E+05	3.3E+03
^{238}Pu	3.5E+04	3.5E+02
^{239}Pu	3.3E+04	3.3E+02
^{240}Pu	3.3E+04	3.3E+02
^{90}Sr+D	1.9E+05	1.9E+03

a For risk = 1E-4.
b For risk = 1E-6.

The hypothetical future off-site resident scenario assumes that a resident receptor will move to a location close to the WOC downgradient of the ORNL SIOU sometime in the future when neither DOE institutional controls nor state controls on WOC surface water used at the DOE-Oak Ridge Reservation are being enforced. This is considered highly unlikely and conservative and would, if at all, occur far into the future. In addition, the hypothetical future off-site resident is unlikely to ingest only water from the surface waters of WOC. Thus, the assumption that the hypothetical future off-site resident ingests 2 L/day of WOC surface waters is very conservative.

The contribution of radionuclide contamination to WOC from the ORNL SIOU assumes conservative release and fate and transport mechanisms. Although the groundwater flow model has been calibrated for site-specific conditions in the RI/FS, the groundwater table and flow patterns should be affected by the absence of the standing surface water bodies of the impoundments subsequent to remediation. Indeed, the release of contaminants from the subimpoundment soils assumes leaching through horizontal groundwater contact flow, which may be minimized or eliminated if the groundwater table drops after remediation and equalization have taken place. Similarly, the solute transport and release to the surface waters of WOC may be affected by the post-remediation conditions at the ORNL SIOU.

4.2 SUBIMPOUNDMENT SOIL CHARACTERISTICS

The RI/FS identified the subimpoundment soils to have different physical and chemical characteristics than the sediments in the ORNL SIOU. The subimpoundment soils are believed to have similar characteristics to a natural clay. However, the subimpoundment soils have not been extensively characterized and uncertainty exists in several key properties affecting source release of possible contamination and groundwater flow. As a proxy of these physical and chemical properties, the characteristics of the sediments, which have been characterized extensively, were used to represent the subimpoundment soils. This is a conservative assumption since the contaminant concentrations, the source release, and the water flow properties of the sediments are believed to result in higher risks for the exposure scenarios under consideration. A potential caveat is the ability of clay materials to tightly bind and/or adsorb radionuclide contaminants; thus, source release and flow properties would be even further reduced, but the total contaminant concentration might be higher than expected for specific radionuclides.

4.3 THRESHOLD SCREENING VALUE CALCULATIONS

Uncertainties in the threshold screening value calculations reflect the uncertainties in the scenario selection and the subimpoundment soil characteristics mentioned above. In addition, the calculations use regulatory-approved toxicity values, namely radionuclide excess lifetime cancer risk slope factors promulgated by EPA (EPA HEAST database), which were derived for a long-term exposure duration and wide distribution extent over the source area. The use of these radionuclide excess lifetime cancer risk slope factors is appropriate for the hypothetical future off-site resident scenario where the receptor may be exposed to radionuclide contamination in WOC surface water for longer periods of time, but is conservative when applied to the short-term exposure conditions of the hypothetical future excavation worker.

5. SUMMARY AND CONCLUSIONS

Impoundments A (3524) and B (3513) of the ORNL SIOU will be remediated to the requirements stated in the ROD (DOE 1997a). The ROD is specific in the extent of remediation, namely all sediments and 0.03 m (0.1 ft) of subimpoundment soils. It does not provide threshold screening values to determine if potential residual contamination may need to be addressed in subsequent remediation actions as part of the Bethel Valley Watershed project.

This analysis provides additional information that may assist field personnel and project managers in determining if potential residual contamination in the subimpoundment soils will pose risks to future receptors. The estimation of threshold screening values was based on two previous analyses, *Characterization of Potential Radiation Dose and Risk Following Remediation of the ORNL Surface Impoundments Operable Unit* (DOE 1998) and *Evaluation of Potential Impact of Residual Contamination in Impoundment 3513 at the Oak Ridge National Laboratory, Oak Ridge, Tennessee* (Jacobs 1998), with minor modifications of the base assumptions and exposure scenarios.

Two hypothetical exposure scenarios are used in this analysis: a hypothetical future excavation worker scenario and a hypothetical future off-site resident. Both scenarios do not reflect the current use patterns of the ORNL SIOU area, but are conservative estimates of reasonable maximum exposure scenarios that assume DOE no longer has institutional control of the ORNL SIOU area. The results of the hypothetical future excavation worker scenario are shown in Table 2 and Table 4.

For the hypothetical future off-site resident, ^{90}Sr was evaluated as the most significant risk contributor, and the results are shown in Table 3.

It is recommended that the threshold screening values in Table 2 be used if there is no water present in the impoundments. It is highly likely, however, that water will be present. When water is present, it is recommended that the threshold screening values in Table 4 are used. The threshold screening values in Tables 2 and 4 are not actionable levels for this site. Further, they are in no way to be considered as threshold screening values that are applicable to the Bethel Valley Watershed ROD Project. Instead, the threshold screening values presented in this report are a tool for the project team to evaluate the levels of contamination left in the subimpoundment soils. If the threshold screening values are exceeded, further remedial action may not be required; however, it may be necessary reevaluate the efficiency of the remediation.

Numerous uncertainties in the estimation of risk-based threshold screening values exist and are discussed in this report.

6. REFERENCES

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