APPENDIX K

Baseline Risk Assessment

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K1.0 BASELINE RISK ASSESSMENT

The SLDS is one of two separate geographical areas collectively referred to as the SLS. These two areas are comprised of multiple properties and are located in two distinct areas: downtown St. Louis City and NC (Figure 1-1). These two areas are designated as the SLDS and the NC sites, respectively. The SLDS is located in an industrial area in the eastern portion of the City of St. Louis, just west of the Mississippi River. The SLDS is comprised of approximately 210 acres of land, which includes the former Mallinckrodt property and 38 surrounding VPs. The former Mallinckrodt property and the surrounding VPs have the potential for radiological and chemical contamination as a result of the historical MED/AEC operations and/or subsequent transportation, storage, or migration of MED/AEC-related residues.

Descriptions of all of the VPs are provided in Table 1-1. The SLDS is divided into two OUs. One OU addresses accessible soil and ground water, which are covered by the 1998 ROD. The other OU addresses the inaccessible soil (i.e., the ISOU), which includes all media at the SLDS not covered by the 1998 ROD that may have become contaminated as a result of the deposition or migration of MED/AEC-related contaminated media. Specifically, the ISOU media of concern include inaccessible soil, soil on building/structural surfaces, sewer sediment, and soil adjacent to sewers. ISOU media do not include surface water or sediment in the Mississippi River. A conceptual view of the inaccessible areas is shown on Figure 1-2.

This ISOU BRA was conducted primarily to estimate and characterize baseline doses and risks to the most likely human receptors identified at the SLDS as a result of potential current and future exposures to radiological and metal COPCs identified in ISOU media (Section 4.0). As previously discussed in Section 1.1.1, radiological and metal COPCs that were determined to be present in ISOU media above corresponding human health risk-based PRGs, as a result of former MED/AEC operations, are being evaluated and considered for further actions. Only metal COPCs located within the boundary of the former uranium-ore processing area, as identified in Figure 1-2, or those that are associated with the sewers, are considered for further actions. Additionally, this BRA includes a SLERA, which follows guidance provided in the USEPA's *Ecological Risk Assessment Guidance for Superfund* [ERAGS]*: Process for Designing and Conducting Ecological Risk Assessments* (USEPA 1997b) and USACE's *Environmental Quality – Risk Assessment Handbook, Volume II: Environmental Evaluation* (USACE 2010b). Thus, the BRA consists of two main components: the HHRA (Section K2.0) and the SLERA (Section K3.0). Section K4.0 provides a high-level summary of both the HHRA and SLERA.

Supporting analytical data, information, and calculations to this BRA are provided in the following appendices:

- Appendix E – Radiological and Metals Analytical Data Summaries and Figures for Inaccessible Soil by Property;
- Appendix F – Data: Radiological Building Survey Results by Property and Building;
- Appendix J – Radiological and Metals Analytical Data Summaries and Figures for Sewers and Inaccessible Soil Associated with Sewers by Plant or Property Area;
- Appendix L – Radiological and Metals Analytical Data Summaries and Figures for Accessible Soil by Property;
- Appendix M – Exposure Point Concentration Calculations for Radiological COPCs;
- Appendix N – Exposure Point Concentration Calculations for Metal COPCs;

- Appendix O – RESRAD Model Outputs: Radiological Dose and Risk Calculations for Inaccessible Soil and Sewer Soil Borehole Locations;
- Appendix P – RESRAD-BUILD Model Outputs: Radiological Dose and Risk Calculations for Exterior Building Surfaces;
- Appendix Q – Dose and Risk Calculations for Exposures to Metal COPCs in Inaccessible Soil, Sewer Sediment, and Soil Adjacent to Sewer Lines;
- Appendix R – Ecological Checklist for the SLDS ISOU; and
- Appendix S – Derivation of Gross Activity Derived Concentration Guideline Levels for the St. Louis Downtown Site.

K2.0 HUMAN HEALTH RISK ASSESSMENT

The scope of the HHRA includes an evaluation of dose and risk of all media not covered by the 1998 ROD (USACE 1998a), as previously described in detail in Section 1.1.2, that may have become contaminated as a result of the deposition or migration of MED/AEC-related contaminated media, and that exceed the health-based PRGs presented in Section 4.0. These media include inaccessible soil, soil on interior and exterior building surfaces, sewer sediment, and soil adjacent to sewer lines. Additionally, dose and risk were also characterized for radiological and metal COPCs in SLDS background soil and sewer sediment in an effort to assess background contributions to ISOU dose and risk. No background data are available for building surfaces. In order to evaluate ISOU media, this HHRA was prepared using analytical data acquired primarily during the ISOU RI, as well as other select data from USACE investigations at the SLDS. Potential risk and dose to individuals from assumed exposures to radiological and metal COPCs are assessed under sitewide and property-specific scenarios. All HHRA evaluations are consistent with the current and expected future land use of the SLDS as a heavily industrial area in an urban setting. The evaluated receptor scenarios for ISOU media include the following:

- industrial worker exposures to inaccessible soil,
- construction worker exposures to inaccessible soil,
- utility worker exposures to inaccessible soil,
- recreational user exposures to inaccessible soil in the levee areas associated with the St. Louis Riverfront Trail,
- industrial worker exposures to interior building surfaces,
- maintenance worker exposures to exterior building surfaces,
- sewer maintenance worker exposures to sediment inside of sewer lines, and
- sewer utility worker exposures to soil adjacent to sewer lines.

In addition to the previously listed receptors evaluated under current and future industrial land use scenarios, a hypothetical, future, resident gardener scenario was evaluated separately for the ISOU. Because current land use is predominantly industrial/commercial, and land use is expected to remain as such for the foreseeable future, it is recommended that scenarios assuming industrial land use be used as the basis for determining future actions at the ISOU. The hypothetical resident gardener was evaluated as an unlimited use and unrestricted exposure scenario for only informational purposes to facilitate future decision making as needed. It is for these reasons that the evaluation methodologies and results of the residential HHRA are presented separately, in Attachment K-1 to this appendix.

The HHRA facilitates the identification of those SLDS properties that should be retained for further evaluation in the FS. COPCs that result in target dose or risk criteria being exceeded are also being further evaluated in the FS.

Although the focus of the HHRA is the ISOU media, sitewide and property-specific evaluations are also performed that consider risk and dose status inclusive of both inaccessible and accessible soil areas. These evaluations assume (1) current land use configurations in which ground cover is present over most inaccessible soil areas, but is absent from accessible soil areas, and (2) future land use configurations in which ground cover is absent from both inaccessible and accessible soil areas. In other words, for future exposure scenarios, the HHRA assumes that inaccessible soil has become accessible due to degradation or complete loss of ground cover. The process for evaluating soil in this HHRA is described in later sections of the HHRA, and is also presented schematically, for sitewide and property-specific scenarios in Figures K-1 and K-2, respectively. The following paragraphs briefly describe the results of the HHRA for ISOU media. All properties/locations and media exceeding target dose and risk criteria are being retained for further evaluations in the FS.

Summary of HHRA Results

For the sitewide evaluations in the HHRA, receptor exposures to radiological and/or metal COPCs in the following media result in CRs above background that are within or exceed the USEPA's target CR range: inaccessible soil, combined inaccessible/accessible soil, and soil adjacent to sewer lines. Additionally, the HHRA results indicate that Plant 1 and DT-4 North exhibit radiological doses above background that exceed the target value of 25 mrem/yr. Of the 28 individual properties evaluated for radiological and metal exposures to inaccessible soil and/or combined inaccessible and accessible soil, 23 properties exhibit CRs above background that are within or exceed the USEPA's target CR range. The HHRA also shows that five buildings present at three properties (Plant 1, Plant 2, and DT-10) exhibit CRs for interior surfaces that are within the USEPA's target CR range. Only one building at DT-10 exhibits a CR for exterior surfaces within the USEPA's target CR range. None of the building surfaces exceed the target dose value. The sitewide evaluation of soil adjacent to sewers and the evaluations of eight individual soil locations adjacent to sewers resulted in exceedances of the target dose and/or resulted in the CRs being within or in exceedance of the target CR range for radiological exposures. All of the metal evaluations of soil adjacent to sewers resulted in all CRs and HIs being less than the target CR range and 1.0, respectively. All of the ALM evaluations of soil adjacent to sewers resulted in health risk due to lead being less than the USEPA's benchmark criterion. Of the metal COPCs evaluated in inaccessible soil (arsenic) and soil adjacent to sewers (arsenic, cadmium, and lead), ingestion of arsenic was the predominant contributor to risk. None of the sewer sediment locations exceed target dose or risk criteria.

K2.1 INTRODUCTION

The SLDS is comprised of numerous former Mallinckrodt plant areas and VPs. Each property quantitatively evaluated in this HHRA, along with specific buildings and locations within each property, is considered an exposure area. The ISOU media being evaluated on a sitewide basis (all media except for building surfaces), as well as on a property-specific or sampling location-specific basis, consist of the following, for which receptor scenarios have been developed:

- Soil that is inaccessible due to the presence of buildings and other permanent structures, including the subsoil within the footprint of a structure of which remediation would reasonably be expected to affect the stability of the structure;
- Soil located under active RRs, including the supporting soil in the associated ROW;
- Soil located under roadways, including the supporting soil in the associated ROW;
- Soil on the exteriors and interiors of buildings and permanent structures (e.g., tanks, bridges, sheds, loading docks, utility poles, traffic signals, piping, rail tracks, and equipment boxes);
- Sewers (e.g., structures and interior sediment) not directly encountered within an excavation area during the remedial action conducted under the 1998 ROD; and

- Soil adjacent to sewers located beneath buildings, permanent structures, RRs, and/or roadways.

This HHRA presents human health dose and risk information specific to each receptor scenario, along with an overall analysis of uncertainty, as an aid in the decision-making process. Characterizing baseline human health dose and risks, both sitewide and at each property, provides stakeholders with information that will be helpful to make decisions to protect human health and the environment, if necessary. The expected end-use of these dose and risk estimates is the recommendation of ISOU media, properties, buildings, and/or locations for further evaluation in the FS.

Both current and expected future land uses at the SLDS have been considered in developing exposure scenarios for each property or building associated with past MED/AEC operations, as well as for those that have been potentially impacted by those operations. Given the current land use and the long history of the SLDS as a heavily industrial and urban setting for more than 100 years, it is expected that the land use will remain as such for the foreseeable future; therefore, evaluations in this HHRA focus on current and future exposure scenarios consistent with this land use. The distinction between current and future exposures is applied mainly to evaluations of inaccessible soil exposures, as opposed to the other ISOU media, which consider no real distinction between current and future exposures. Inaccessible soils are being evaluated under sitewide and property-specific evaluations. Additionally, for the industrial worker (i.e., the limiting receptor) and recreational users of the St. Louis Riverfront Trail, combined inaccessible and accessible soil evaluations are conducted on both a sitewide and property-specific basis to determine overall risk and dose status of the SLDS and each property.

Under current land configurations, various types of ground cover are present across the SLDS ISOU study area in the forms of buildings/structures, RRs, roadways, the levee, and pavement, which affect the significance and completeness of the direct contact exposure pathways (i.e., exposures via ingestion, dermal contact, and dust inhalation). These covers are comprised of consolidated and unconsolidated materials. Examples of consolidated materials include asphalt and concrete. Unconsolidated materials include soil and gravel. Of all of these materials, soil as a form of ground cover is the least dense and, therefore, provides the least protection for individuals from external radiological exposures. Therefore, for the purpose of presenting health-conservative evaluations in the HHRA, radiological exposure evaluations of all inaccessible soil areas under the current scenario conservatively assume a 0.3048-m-thick soil cover. However, for the properties in which the levee exists (DT-2, DT-9 Levee, and DT-15), a minimal thickness of 1 m is assumed. All evaluations of the levee for the non-soil-intrusive scenarios (industrial worker and recreational user) assume that the levee is always present in both the current and future timeframes. In the FS, the health protectiveness of the actual existing cover material present in each area will be evaluated to support development of remediation goals and remedial alternatives. For evaluations of future scenarios, the degradation or complete loss of ground cover in the inaccessible soil areas is assumed to estimate reasonable worst case exposures. Under both current and future scenarios, sitewide and property-specific evaluations of combined inaccessible and accessible soil exposures to the industrial worker and recreational user assume no ground cover present in the accessible soil areas.

Radiological doses and CRs are estimated using the DOE's RESRAD and RESRAD-BUILD computer codes for soil/sediment and structural surfaces, respectively. Human health risks are characterized herein for metal COPCs as estimates of excess lifetime CRs for carcinogenic effects and non-carcinogenic HIs for systemic effects. CRs and non-carcinogenic hazards are estimated for metal exposures using mathematical algorithms presented in various USEPA risk assessment guidance documents. The ALM was used to estimate the risk of elevated fetal blood lead levels in a pregnant female worker following assumed exposures to lead in soil adjacent to sewer lines (USEPA 2003b). This HHRA has been conducted based on the methodology presented in Appendix A of the RI WP (USACE 2009a) and has applied methods from the following USEPA guidance documents:

- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual: Part A* (USEPA 1989a);
- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual: Part B, Development of Risk-Based Preliminary Remediation Goals* (USEPA 1991a);
- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual: Part E, Supplemental Guidance for Dermal Risk Assessment* (USEPA 2004b);
- *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual: Part F, Supplemental Guidance for Inhalation Risk Assessment* (USEPA 2009b);
- *Exposure Factors Handbook: 2011 Edition* (USEPA 2011);
- *Child-Specific Exposure Factors Handbook* (USEPA 2008);
- *Guidance for Data Usability in Risk Assessment (Part A)* (USEPA 1992b);
- *Regional Screening Level*s Tables (USEPA 2012a);
- *Guidance for the Data Quality Objective Process* (USEPA 2000);
- *Soil Screening Guidance: User's Guide* (USEPA 1996a);
- *Radiation Exposure and Risk Assessment Manual* (USEPA 1996b);
- *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA 2002a);
- *Supplemental Guidance for Developing Soil Screening Levels at Superfund Sites* (USEPA 2002b); and
- *Recommendations of the Technical Review Workgroup for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil* (USEPA 2003b).

For all ISOU media, the HHRA itself is comprised of several significant steps (identification of COPCs, exposure assessment toxicity assessment, and dose and risk characterization). Thus, the main components of this HHRA are as follows:

- **Section K2.2 – Summary of Data Evaluation and Identification of COPCs:** Briefly summarizes the validity of data acquired during the RI for use in the risk assessment and the identification of COPCs, buildings, and properties, being evaluated in this HHRA, as previously presented in Section 4.0.
- **Section K2.3 – Exposure Assessment:** Presents potentially exposed populations and exposure routes/pathways for the industrial land use CSM, methodology for estimating EPCs, pathway intake equations for metal exposures, and input values for radiological and metal exposure parameters, including overviews of the RESRAD and RESRAD-BUILD computer models used for evaluating radiological exposures to soil/sediment and structures, respectively.
- **Section K2.4 – Toxicity Assessment:** Describes the approach used to evaluate carcinogenic effects from radiological and metal exposures in terms of CRs and non-

carcinogenic effects from metal exposures in terms of hazards, as well as quantitative indices of toxicity used for estimating both potential risks and hazards. The USEPA's ALM for evaluating exposures to lead in soil is also discussed.

- **Section K2.5 – Dose and Risk Characterization:** Describes the methodology used for the estimation of doses and CRs for radiological exposures and CRs and non-carcinogenic HIs for exposures to metals by integrating the results of the exposure and toxicity assessments. Radionuclides and metals contributing predominantly to doses, CRs, and HIs (i.e., as risk drivers), by exceeding target criteria, will be identified as COCs for consideration of future actions.
- **Section K2.6 – Uncertainties Analysis:** Discusses sources and implications of uncertainty in the risk assessment process, including ISOU-specific factors and model-specific factors contributing to the overall uncertainty of the HHRA results.

All figures and tables for Appendix K that are mentioned in the text are presented after the text.

K2.2 SUMMARY OF DATA EVALUATION AND IDENTIFICATION OF CONTAMINANTS OF POTENTIAL CONCERN

All ISOU RI data underwent data validation to determine its usability for risk assessment purposes. Data were qualified accordingly with regard to usability. All RI data were found to be usable and are incorporated into the risk assessment. A detailed evaluation of the data is presented in the QCSR (see Appendix B).

COPCs in ISOU media (inaccessible soil, soil on building surfaces, sewer sediment and soil adjacent to sewer lines) being retained for radiological and/or metals dose/risk evaluations were identified in Section 4.0 through data comparisons with risk-based PRGs.

Both radiological and metals PRGs used for comparisons with concentrations detected in ISOU media are presented in Table 4-1. Descriptions of the risk basis of the PRGs being used to evaluate radiological and metals data are provided in Sections 4.1.1 and 4.1.2, respectively. Identifications of COPCs for each ISOU medium were done on a sitewide basis such that if at least one sample result for a PCOC in a medium exceeded the corresponding PRG, then that PCOC was retained as a COPC for that medium, across all SLDS properties, for quantitative dose and risk evaluation in the BRA. The sections below summarize the sitewide COPCs retained for each ISOU medium.

K2.2.1 Inaccessible Soil Contaminants of Potential Concern

Attachment E-2 of Appendix E presents exceedances of radiological and metal PRGs by individual sample concentrations measured in inaccessible soil. Attachment E-2 of Appendix E also presents summary statistics for each inaccessible soil dataset. The total numbers of inaccessible soil samples collected and analyzed for each of the radiological and metal PCOCs, along with the total numbers of soil PRG exceedances by each PCOC are presented in Table 4-3. As previously stated, one PRG exceedance by at least one sample result throughout SLDS caused the PCOC to be retained as a COPC for the HHRA. Therefore, the following have been identified as sitewide radiological COPCs in inaccessible soil: Ac-227, Pa-231, Ra-226, Ra-228, Th-230, Th-232, U-235, and U-238. Th-228 is not a COPC, because none of the samples collected across any of the SLDS properties had detected concentrations greater than the PRG. Metals were only identified as COPCs if they exceed the PRG within the uranium-ore processing area (see Figure 1-2) by at least one sample result. Therefore, arsenic was identified as the only metal COPC in inaccessible soil within the former uranium-ore processing area.

For the combined inaccessible and accessible soil dose and risk evaluations, the above list of radiological COPCs and arsenic are evaluated for the inaccessible soil areas of each property; whereas, the accessible soil COCs identified in the 1998 ROD and evaluated within the associated PRARs are evaluated for the accessible soil areas of each property. The 1998 ROD identified the following as soil COCs: Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, U-238, arsenic, cadmium, and uranium metal.

K2.2.2 Soil Contaminants of Potential Concern on Building Surfaces

Appendix F shows gross alpha and beta results obtained during from radiological surveys of fixed-point locations on interior and exterior surfaces of buildings. The results of gross alpha surface data comparisons were compared with the interior and exterior surface PRGs presented in Table 4-1. Table 4-6 shows that interior and exterior PRGs were exceeded by surfaces on or within 10 buildings at Plant 1, Plant 2, DT-6, DT-10, and DT-14. The radiological soil COCs that were identified in the 1998 ROD have been retained as the COPCs for soil on building surfaces. This is because it is assumed that the soil on surfaces originated predominantly from accessible soil areas. Therefore, the sitewide radiological COPCs for soil on building surfaces include the following: Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, and U-238. There are no metal COPCs for structural surfaces.

K2.2.3 Contaminants of Potential Concern in Sewer Sediment and Soil Adjacent to Sewer Lines

Sewer sediment and soil adjacent to sewer lines were sampled and analyzed for radiological and metal PCOCs that were identified in the RI WP. Because sediment present in the drains, manholes, and sewers used for MED/AEC operations had not been analyzed for metals during past investigations, metals associated with formerly used pitchblende and domestic ores (i.e., arsenic, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, vanadium, zinc, and uranium metal) were identified as PCOCs in the RI WP for sampling and analysis of sewer sediment, as well as for soil adjacent to sewers.

Attachment J-2 of Appendix J shows radiological and metal data summaries for sewer sediment and soil adjacent to sewer lines, including individual sample results that exceed corresponding soil PRGs, and their summary statistics. Metals in sewer line sediments and in soil adjacent to sewer lines that serviced plants and buildings within the boundary of the former uranium-ore processing area were evaluated as COPCs, even if the sampling locations were outside of the boundary. The total numbers of sewer sediment samples collected and analyzed for each of the radiological and metal PCOCs, along with the total numbers of sediment PRG exceedances by each PCOC, are presented in Tables 4-9 and 4-10. Based on these exceedances, the following radiological and metal PCOCs were retained as COPCs for evaluation of sewer sediment: Ra-226, Ra-228, U-238, and arsenic.

Likewise, the total numbers of soil samples collected adjacent to sewer lines and analyzed for each of the radiological and metal PCOCs, along with the total numbers of PRG exceedances by each PCOC, are presented in Tables 4-11, 4-12, and 4-13. Based on the PRG exceedances, the following radiological and metal PCOCs were retained as COPCs for evaluation of soil adjacent to sewer lines: Ac-227, Pa-231, Ra-226, Ra-228, Th-230, U-238, arsenic, cadmium, and lead.

K2.2.4 Summary of Contaminants of Potential Concern Identified in ISOU Media

The following items summarize the COPCs identified in each of the ISOU media that are being quantitatively evaluated for dose and risk in the HHRA:

- Inaccessible Soil COPCs – Ac-227, Pa-231, Ra-226, Ra-228, Th-230, Th-232, U-235, U-238, and arsenic;
- Interior and Exterior Building Surface COPCs – Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, and U-238;
- Sewer Sediment COPCs – Ra-226, Ra-228, U-238, and arsenic; and
- COPCs for Soil Adjacent to Sewer Lines – Ac-227, Pa-231, Ra-226, Ra-228, Th-230, U-238, arsenic, cadmium, and lead.

K2.3 EXPOSURE ASSESSMENT

To assess potential risks to human health at a given site, exposure must first be evaluated and quantified. At the ISOU, a radiological exposure occurs when there is physical contact between a human receptor and a radiological COPC in the environment, or between a human and the external radiation emitted from the radiological COPC. A metal exposure occurs when there is contact between a human and a metal COPC in the environment. The exposure assessment estimates the magnitude, frequency, duration, and routes of potential exposure to human receptors from COPCs present in ISOU media. An exposure assessment consists of the following elements:

- description of the site setting (previously discussed in Section 3.0);
- identification of the current and future land use and potentially exposed people (receptors);
- identification of pathways through which people may be exposed;
- calculations of EPCs for each COPC; and
- presentation of intake equations, including exposure factors used to estimate intake for each COPC, exposure pathway, and receptor.

A CSM (Figure K-3) has been developed for the ISOU that presents and discusses complete and incomplete exposure pathways identified for ISOU media and receptors under current and future land use scenarios. The current land use scenario assumes that the existing physical configurations at the SLDS remain in place-particularly, the ground cover currently present throughout most of the ISOU areas in the form of buildings, RRs, roadways, and pavement. The future land use scenario assumes that these ground cover features are either completely removed or are allowed to degrade to a point that renders contamination in inaccessible soils physically available for receptor exposures.

Figure K-3 identifies the following types of potential exposure pathways assumed for current and expected future land use scenarios: (1) complete and potentially significant pathways, (2) potentially complete but insignificant pathways, and (3) incomplete pathways. A complete exposure pathway is comprised of each of the following elements:

- a source,
- a mechanism of contaminant release and transport process/medium (e.g., soil),

- an exposure medium and point where humans could contact the contaminated medium, and
- an exposure route (i.e., ingestion, dermal contact, inhalation, or external radiation).

Complete pathways are retained for quantitative evaluations in the BRA. Potentially "complete but insignificant" pathways are considered unlikely, insignificant, or out of scope for the ISOU. Potentially complete but insignificant exposure pathways and incomplete exposure pathways are not quantitatively evaluated in the HHRA. CSM discussions focusing on potential contaminant sources and environmental release/transport mechanisms were provided in Sections 5.1 and 5.2, respectively. Under current configurations (i.e., under ground cover), the only potentially complete exposure pathway for contaminants in inaccessible soil is via the route of external radiation. This HHRA assumes that in the future all inaccessible soil has become accessible and that no ground cover is present to prevent direct contact exposures to radiological and metal COPCs, via the routes of ingestion, dermal contact, or dust inhalation. For soil in inaccessible areas that is not beneath any ground cover, ingestion, dermal contact, inhalation of dust, and external radiation exposures could occur. Exposures to contaminated soil on building surfaces could occur via ingestion, inhalation, and external radiation. Exposures to sediment inside of manholes and sewer lines could occur via ingestion and dermal contact. Finally, exposures to inaccessible soil adjacent to sewer lines can occur via ingestion, dermal contact, inhalation of dusts, and external radiation, following excavation.

Exposure scenarios evaluated in this HHRA are based on land use, identification of potentially exposed individuals, and human exposure routes, which are described in Section K2.3.1. The proper development of EPCs is important in the evaluation of each scenario. Therefore, prior to discussing exposure scenarios in Section K2.3.2, the general methodology for calculating EPCs is presented in Section K2.3.1.

K2.3.1 Quantification of Exposure Point Concentrations

To calculate a CR for radiological and metal COPCs or a non-cancer hazard for metal COPCs, an estimate must be made of the COPC concentration in the environmental medium to which an individual may be exposed. To quantify exposure for each receptor, an EPC, or an upper-bound estimate of the constituent concentration a receptor is likely to come in contact with over the duration of exposure, is calculated. The EPC is used to estimate the dose and intake for each radiological and metal COPC, respectively, by individual receptors, via all complete pathways and media identified in the CSM (Figure K-3). Sections K2.3.1.1, K2.3.1.2 and K2.3.2.3 discuss the general methodologies for calculating property-/receptor-specific EPCs for the following media: inaccessible and combined inaccessible and accessible soil (Section K2.3.1.1), soil on building surfaces (Section K2.3.1.2), and sewer sediment and soil adjacent to sewer lines (Section K2.3.1.3). Table K-1 summarizes the property-specific receptor scenarios evaluated in the HHRA, for which EPCs were determined. The radiological EPCs are presented in Tables K-2A, K-3A, K-3B, K-3C, K-4A, and K-5A. Likewise, EPCs for metal COPCs are presented in Tables K-2B, K-4B, and K-5B. Data inputs and calculation outputs for radiological and metal EPCs are presented in Appendices M and N, respectively. All locations and sample IDs associated with each set of EPC calculations are also presented in Appendices M and N.

An EPC was calculated for each COPC identified within each ISOU medium and is specific to the property, building, or location for which it was applied. If no COPCs were identified, then no EPC was calculated, because the scenario does not require quantitative dose/risk evaluations. Radiological and metal EPCs were determined for inaccessible soil, sewer sediment, and soil adjacent to sewer lines. Although SLDS soil and sediment background data are available for radiological and metal COPCs, background concentrations were not subtracted from sample results prior to, or during, EPC calculations.

In accordance with USEPA guidance (USACE 2002a), the EPC should be the estimate of the average concentration measured over the area to which an individual receptor would be exposed for the duration of the exposure. Because of the uncertainty associated with estimating the true average concentration at a site, the USEPA recommends that the lower of the 95 percent UCL or the maximum detected concentration be used to estimate the average site concentration for a reasonable maximum exposure scenario. Essentially, the 95 percent UCL is a conservative, upper-bound estimate of the mean concentration and, by using the 95 percent UCL, the probability of underestimating the true mean is less than 5 percent. The 95 percent UCL also accounts for uncertainties resulting from limited sampling (Gilbert 1987). Under certain situations (e.g., small sample sizes), the 95 percent UCL may be greater than the maximum detected concentration. For this reason, the USEPA recommends the selection of the lower of the two values as the appropriate EPC, which was applied for both radiological and metal COPCs.

The 95 percent UCL was calculated using the ProUCL statistical software package. Before calculating the 95 percent UCL, the distribution of the dataset was determined (e.g., normal, lognormal, non-parametric). Subsequently, the 95 percent UCL was calculated based on the distribution determined for the dataset. To simplify this calculation process, the USEPA's ProUCL software was used to determine both data distributions and the corresponding 95 percent UCLs for each set of data. For non-detect metals results (i.e., qualified "U" or "UJ"), the 95 percent UCL cannot be estimated unless numerical values are assigned. ProUCL has goodness-of-fit tests for normal, lognormal, and gamma distributed data sets with or without non-detect results. For consistency with past and ongoing evaluations of non-detects being conducted in support of remedial actions under the 1998 ROD, the USEPA's methodology (USEPA 2002a) is implemented for evaluating non-detects in metals datasets. In other words, for the purposes of calculating 95 percent UCLs, as well as descriptive statistics (i.e., mean, standard deviation, etc.) for metals evaluated in this HHRA, non-detect results were replaced with proxy values equivalent to one-half the detection limit, prior to application of ProUCL.

For this HHRA, the greater of the two results obtained for a COPC from analysis of a field duplicate pair was used in the calculation of EPCs to avoid the "double-counting" of data from any one soil sampling location/depth. Split samples were not included in datasets used to calculate EPCs. Split sample data are used only for QA purposes, the results of which are reported and discussed in the QCSR (Appendix B), because the field duplicate pair and split sample are analyzed at different laboratories. For risk assessment purposes, it is preferred that data generated from one laboratory (i.e., the primary laboratory) be used to calculate EPCs, unless the dataset must also include historical data generated by a different laboratory. Using RI data generated from only the primary laboratory eliminates uncertainties that can result from inter-laboratory variability.

K2.3.1.1 Exposure Point Concentrations for Inaccessible Soil and Combined Inaccessible Soil and Accessible Soil

For all sitewide and property-specific inaccessible soil and combined inaccessible/accessible soil dose and risk evaluations, EPCs were first calculated separately for inaccessible soil and accessible soil, each of which are based on the lesser of the 95 percent UCL or maximum detection. As described in Section K2.5.3, the resulting EPCs are used to determine risks and doses for inaccessible and accessible soil areas separately for each sitewide and property-specific scenario. Afterward, for any given property, or for SLDS (sitewide), the combined inaccessible/accessible soil doses and risks are finally determined as the area-weighted average of the doses and risks determined separately for the inaccessible and accessible soil areas. Therefore, combined inaccessible/accessible soil EPCs are never actually calculated. For metals, sitewide and property-specific EPCs for inaccessible and accessible soil areas are determined using data from only those properties within the boundary of the former uranium ore processing area. For properties through which the levee and St. Louis Riverfront Trail runs, only radiological data from DT-2 , DT-9 Levee, and DT-15 are used for calculating EPCs for inaccessible and accessible soil areas.

K2.3.1.2 Radiological Exposure Point Concentrations for Soil on Building Surfaces

According to the CSM, industrial workers and maintenance workers at the SLDS plant properties and VPs are being evaluated for exposures to radiological COPCs on interior and exterior building surfaces, respectively. All radiological survey measurements for buildings were analyzed as gross alpha activities. If at least one sample result for building surfaces exceeded the gross alpha DCGL, then the gross alpha results (either all exterior or all interior) from the survey were inserted into the USEPA-designed software, ProUCL, to calculate the 95 percent UCL. The lesser of the ProUCL-recommended 95 percent UCL or the maximum gross alpha measurement was then converted from dpm/100 cm^2 to pCi/m^2 as follows:

$$gross\ alpha\ \left({}^{pCi}/_{m^2}\right) = gross\ alpha\ \left({}^{dpm}/_{100\ cm^2}\right) \times 10{,}000\ {}^{cm^2}/_{m^2} \times \left({}^{1\ pCi}/_{2.22\ dpm}\right)$$

This conversion was conducted to adjust the gross alpha units into those units required for the RESRAD-BUILD parameter input.

Because survey instrumentation could not distinguish between individual radionuclide activities (i.e., instruments only provide a gross alpha value), it was assumed that any areas exceeding PRGs must have been contaminated from the surrounding contaminated soil and, therefore, would have the same activity fractions as the soil at the SLDS. Individual radionuclide-specific EPCs were calculated by multiplying the gross alpha value (lesser of the 95 percent UCL and maximum gross alpha) by the radionuclide-specific activity fraction. Activity fractions were calculated by dividing individual radionuclide soil concentration values by the sum of soil concentration values for all COCs. Soil concentration values used for this calculation were selected from Table 3.9 of the 1993 BRA (DOE 1993). SLDS-specific activity fractions were calculated as needed to appropriately assign portions of the average gross alpha 95 percent UCL value into radionuclide-specific EPCs required for RESRAD-BUILD parameter inputs. SLDS-specific soil activity fractions are presented in Table K-3A.

Interior surfaces at seven buildings exceeded the gross alpha PRG for interior surfaces:

- Plant 1 Building 7,
- Plant 1 Building 26,
- Plant 2 Building 41,
- Plant 2 Building 508,
- DT-6 Storage Building,
- DT-10 Metal Storage Building, and
- DT-10 Wood Storage Building.

Exterior surfaces at four buildings/locations exceeded the gross alpha PRG for exterior surfaces:

- Plant 1 Building 25,
- Plant 1 Building X,
- DT-10 Wood Storage Building, and
- DT-14 Horizontal Beam between the L-Shaped Building and Brick Building.

Surface EPCs were calculated for each radiological COPC. All interior data were used to calculate the interior EPC for each COPC in that building. All interior surface EPCs are presented in Table K-3B. Likewise, all exterior data were used to calculate the exterior EPC for each COPC for that building. All exterior surface EPCs are presented in Table K-3C.

K2.3.1.3 Exposure Point Concentrations for Sewer Sediment and Soil Adjacent to Sewer Lines

For sewer sediment and soil adjacent to sewer lines, sitewide and sample location-specific EPCs were calculated. The sitewide EPCs for each sewer medium were determined to be the lesser of the 95 percent UCL or maximum detection for all sample locations across the SLDS for the medium. Location-specific, rather than property-specific, EPCs were determined for each sewer sediment location and soil location adjacent to sewer lines, because of the large distances between individual sewer sediment locations and soil boreholes. The location-specific sewer sediment EPCs are simply the reported concentrations at each location, because only one sample was collected per location. However, because soil samples adjacent to sewer lines were collected at a frequency of two or three depth intervals per location, the location-specific EPCs for radiological COPCs, arsenic and cadmium were determined to be the maximum detection of the soil samples collected from within each borehole location adjacent to a sewer line. Because 95 percent UCLs cannot be reliably determined for only two or three samples, the location-specific EPCs for all boreholes were the maximum detected concentrations. Because only one sample was collected from each location, with EPCs are represented by the measured sample concentrations reported for each COPC at each location. Additionally, sitewide EPCs were calculated for each COPC to determine dose and risk estimates for all sampled sewer sediment locations. Sitewide EPCs and location-specific EPCs for lead in soil adjacent to sewer lines were calculated as mean concentrations in accordance with USEPA (2003b) methodology for assessing risks to adult workers.

K2.3.2 Identification of Land Use and Potential Exposure Scenarios

The SLDS is located in a heavily industrial/urban setting. Current land use is predominantly industrial and commercial and is expected to remain as such for the foreseeable future. According to the City of St. Louis Strategic Land Use Map, which was adopted by the City of St. Louis' Planning Commission on January 5, 2005, all SLDS properties are listed as "Business and Industrial Preservation and Development Area" or "Business and Industrial Development Area" (City of St. Louis 2012a). The long-term plans by the City of St. Louis for the SLDS area are to retain the industrial uses, encourage the wholesale produce district, and phase out the remaining marginal residential uses. Therefore, this HHRA focuses on receptors that are likely to be exposed to contaminated inaccessible soil, soil on building surfaces, sewer sediment, and soil adjacent to sewer lines under current and future industrial land use scenarios.

The main distinction between current and future scenarios pertains to ground cover assumptions applied during evaluations of exposures to inaccessible soil. There is no real distinction assumed between current and future potential human exposures to the ISOU media. Future land use of the SLDS is expected to be heavily industrial; therefore, this HHRA does not assume that the properties are redeveloped for land uses other than industrial/commercial use. This approach ensures that a reasonable maximum risk will be characterized under existing land use patterns and that all potential receptors will be adequately protected.

- *Current Industrial Worker (Ground Cover Present) and Future Industrial Worker (Ground Cover Absent)* – The current industrial worker evaluation assumes existing ground cover remains intact so that the only potentially complete exposure pathway for this receptor is external radiation. In the future, ground cover is assumed to be absent or degraded sufficiently so that a future industrial worker could be exposed via external radiation, soil ingestion, dermal contact with soil, and dust inhalation. Industrial workers are individuals working mainly indoors with some outdoor activities at the plants, industrial/commercial VPs, RRs, and roadways. This group includes site workers performing daily job activities specific to the SLDS property/VP at which they are employed (e.g., working at various plant processes and industrial/commercial work activities at the SLDS and VPs, office workers, and building maintenance employees). Industrial worker exposures to inaccessible soil are assumed to occur property-wide and are not limited to any particular area of a property. Based on the industrial worker soil exposure frequencies and durations, this receptor is assumed to be the maximally exposed individual (i.e., limiting receptor) at the ISOU. Therefore, this receptor is evaluated at all ISOU properties for exposures to inaccessible soil and to combined inaccessible/ accessible soil.
- *Current/Future Recreational User* – Recreational users are assumed to use the St. Louis Riverfront Trail along DT-2, DT-9 Levee, and DT-15 for walking, jogging, and biking.
- *Current/Future Construction Worker* – The construction worker is assumed to be a contractor (i.e., not a SLDS/VP employee) who performs one-time, deep excavation and construction activities at the ISOU. This receptor group is assumed to be exposed at all SLDS plants, industrial/commercial VPs, RRs, and roadways. Because this scenario assumes work in excavations, ground cover is assumed to absent under both current and future exposure scenarios. Because construction can occur anywhere within the SLDS study area or within any given property at the SLDS, this scenario is evaluated for sitewide and property-specific inaccessible soil exposures.
- *Current/Future Utility Worker* – In a manner consistent with the 1998 ROD, a utility worker is assumed to perform one-time work on utilities (i.e., repairing, maintaining, and replacing subsurface utilities), within a deep excavation, for a short time duration with an equal probability of performing this work at any location across each individual property, as well as across all of the SLDS. Because this scenario assumes work in excavations, ground cover is assumed to absent under both current and future exposure scenarios. This receptor is evaluated for exposures to COPCs in inaccessible soil areas across each property and all of the SLDS.
- *Current/Future Industrial Worker* – Industrial workers may be exposed to contaminated soil on interior and exterior building surfaces in either the current or future timeframes. Exposures to exterior surfaces are assumed to occur during exterior building or structural maintenance work; therefore, industrial workers exposed to exterior surfaces are being evaluated as maintenance workers. Exposures to contaminated soil on surfaces are assumed to be specific to the building to which the exposures occur; therefore, sitewide evaluations of buildings are not considered in the HHRA.

- *Current/Future Sewer Maintenance Worker* – Sewer maintenance workers are assumed to perform infrequent work inside of sewers and manholes. Sewer sediment exposures for this receptor are evaluated on a sitewide and sampling location-specific basis.
- *Current/Future Sewer Utility Worker* – This receptor is assumed to perform work specifically on the outside of lines, usually within a deep excavation and for a short duration. During this time, exposures are likely to occur to the soil adjacent to the outside of the sewer lines. In an effort to evaluate possible contamination specifically from the sewers, this receptor is evaluated separately from the current utility worker described in the fourth bullet in this list.

In addition to the above receptors evaluated under current and future industrial land use scenarios, a hypothetical, future, resident gardener scenario was evaluated for the ISOU. Because current land use is predominantly industrial/commercial, and land use is expected to remain as such for the foreseeable future, it is recommended that scenarios assuming industrial land use be used as the basis for determining future actions at the ISOU. The hypothetical resident gardener was evaluated as an unlimited use and unrestricted exposure scenario for only informational purposes to facilitate future decision making as needed. It is for these reasons that the evaluation methodologies and results of the residential HHRA are presented separately, in Attachment K-1 to this appendix. Attachment K-2 presents inaccessible soil data comparisons with USEPA risk-based residential PRGs for the purpose of determining COPCs for the residential scenario.

The following subsections (K2.3.2.1 through K2.3.2.5) summarize the exposure scenarios as they relate to each ISOU medium under industrial land use considerations, with more specific information regarding receptor-specific exposure routes being quantitatively evaluated for dose and risk.

K2.3.2.1 Inaccessible Soil

For the sitewide and property-specific scenarios, the evaluation of inaccessible soil beneath buildings, permanent structures, RRs, and roadways includes all inaccessible soil areas within SLDS and within each individual property, respectively. However, for the industrial worker and recreational user, this HHRA determines the sitewide and property-wide dose/risk status of all soil (i.e., inaccessible and accessible soil combined).

As previously stated, different assumptions apply to the evaluations of inaccessible soil under current and future scenarios. This distinction applies mainly to the industrial worker. Under the current land use scenario, industrial worker evaluations of inaccessible soil assume the presence of existing physical configurations relative to the ground cover, which is present over most inaccessible soil areas (i.e., in the forms of buildings/structures, roadways, RRs, pavement, etc.). The current industrial worker scenario also assumes that ground cover is absent over all accessible soil areas, for consistency with past and ongoing evaluations being conducted to support remedial actions under the 1998 ROD. The future land use scenario assumes that ground cover is absent from both inaccessible and accessible soil areas. In other words, for future exposure scenarios, the HHRA assumes that inaccessible soil has become accessible for industrial worker exposures due to degradation or complete loss of ground cover. Although the presence of ground cover may not eliminate external gamma exposures to radiological COPCs in the underlying inaccessible soil, it likely prevents direct contact exposures to the underlying radiological and metal COPCs by the industrial worker that would otherwise occur via incidental ingestion, dermal contact, and inhalation of dusts. Therefore, the difference between the current and future exposure scenarios for the industrial worker is the level of health protectiveness or non-protectiveness afforded by the presence or absence of ground cover. However, for the current scenario, exposures to all radionuclides, via all pathways, are evaluated using the RESRAD model, even though ground cover is assumed to be present, because RESRAD incorporates a cover erosion rate. On the other hand, calculations of metals exposures do not incorporate cover erosion; therefore, all metals exposure pathways are treated as being incomplete under the current scenario. In the future scenario, in which no ground cover is assumed for inaccessible soil or accessible soil areas, all exposure pathways are assumed to be complete for both radiological and metal COPCs.

The recreational user is applied to evaluate potential inaccessible soil exposures to users of the St. Louis Riverfront Trail, which traverses the levee along the Mississippi River, through the following properties: DT-2, DT-9 Levee, and DT-15. The inaccessible soils in these areas are beneath the levee and are assumed to remain beneath the levee under current and future scenarios. Therefore, both current and future scenarios are the same for the recreational user relative to exposure assumptions. Although the inaccessible soil at the St. Louis Riverfront Trail is beneath the levee, it is conservatively assumed that the recreational users are exposed to radiological COPCs via ingestion, dust inhalation, and external radiation.

Construction and utility worker exposures to inaccessible soil always assume that excavation is required in which the cover must be removed, thereby facilitating exposures to radiological and metal COPCs under current and future scenarios. Therefore, the exposure assumptions for these receptors are the same under current and future conditions.

The current industrial worker, future industrial worker, current/future construction worker, and the current/future utility worker are evaluated for sitewide exposures, as well as for property-specific exposures, to inaccessible soil; therefore, sitewide and property-specific EPCs are calculated for these receptors across all properties. Inaccessible soil EPCs for the recreational user are calculated for each of the three properties through which the St. Louis Riverfront Trail runs: DT-2, DT-9 Levee, and DT-15. Additionally, the recreational user is being evaluated for inaccessible soil across all three properties combined (i.e., the "St. Louis Riverfront Trail properties"). The industrial workers and the recreational users are evaluated for both inaccessible soil exposures, and then are evaluated again for combined inaccessible/accessible soil exposures. The purpose of the latter evaluation is to assess doses and risks for all soils at the SLDS and for all soils within each of the individual properties. For SLDS evaluation and for each property evaluation, separate EPCs are calculated for inaccessible and accessible soils. Inaccessible soil dose and risk is determined using the inaccessible soil EPC, while accessible soil dose and risk is determined using the accessible soil EPC. After summing dose and risk across all pathways, the combined inaccessible/accessible soil dose or risk is determined as an area-weighted average of the total inaccessible and total accessible soil doses or risks. Calculation of the combined inaccessible/accessible soil dose and risk as area-weighted averages allows for RESRAD model application of ground cover over inaccessible soil areas and no ground cover over accessible soil areas when evaluating the current industrial worker and the current/future recreational user scenarios. This evaluation would not be possible if area weighting was applied to EPCs rather than to doses or risks. For evaluations of industrial worker exposures to metal COPCs in inaccessible soil, only the future scenario is evaluated, because the presence of ground cover in the current scenario results in incomplete exposure pathways.

The following items summarize the inaccessible soil and combined inaccessible/accessible soil exposure scenarios. These scenarios are also reflected by property in Table K-1. Tables presenting the EPCs associated with each scenario are presented in parentheses.

Current Industrial Worker Exposures to Radiological COPCs: Sitewide and Property-Specific Evaluations across All Properties (EPC Table K-2A) include:

- incidental ingestion of inaccessible soil (ground cover present),
- incidental ingestion of accessible soil (ground cover absent),
- inhalation of particulate dust emissions from inaccessible soil (ground cover present),
- inhalation of particulate dust emissions from accessible contaminated soil (ground cover absent),
- external gamma exposures from inaccessible soil (ground cover present),
- external gamma exposures from accessible soil (ground cover absent), and
- all exposure routes – combined (area-weighted average) inaccessible soil (ground cover present) and accessible soil (ground cover absent).

Future Industrial Worker Exposures to Radiological and Metal COPCs: Sitewide and Property-Specific Evaluations across All Properties (EPC Tables K-2A and K-2B) include:

- incidental ingestion of inaccessible soil (ground cover absent),
- incidental ingestion of accessible soil (ground cover absent),
- dermal contact with inaccessible soil (ground cover absent) (metals only),
- dermal contact with accessible soil (ground cover absent) (metals only),
- inhalation of particulate dust emissions from inaccessible soil (ground cover absent),
- inhalation of particulate dust emissions from accessible soil (ground cover absent),
- external gamma exposures from inaccessible soil (ground cover absent),
- external gamma exposures from accessible soil (ground cover absent), and
- all exposure routes – combined (area-weighted average) inaccessible soil (ground cover absent) and accessible soil (ground cover absent).

Current/Future Recreational User Exposures to Radiological COPCs: Individual and Combined St. Louis Riverfront Trail Properties (DT-2, DT-9, and DT-15) (EPC Table K-2A) include:

- incidental ingestion of inaccessible soil (ground cover [levee] present),
- incidental ingestion of accessible soil (ground cover absent),
- inhalation of particulate dust emissions from inaccessible soil (ground [levee] cover present),
- inhalation of particulate dust emissions from accessible soil (ground cover absent),
- external gamma exposures from inaccessible soil (ground cover [levee] present),
- external gamma exposures from accessible soil (ground cover absent), and
- all exposure routes – combined (area-weighted average) inaccessible soil (ground cover [levee] present) and accessible soil (ground cover absent).

Current/Future Construction Worker Exposures to Radiological and Metal COPCs: Sitewide and Property-Specific Evaluations across All Properties (EPC Tables K-2A and K-2B) include:

- incidental ingestion of inaccessible soil (ground cover absent),

- dermal contact with inaccessible soil (ground cover absent) (metals only),
- inhalation of particulate dust emissions from inaccessible soil (ground cover absent), and
- external gamma exposures from inaccessible soil (ground cover absent).

Current/Future Utility Worker Exposures to Radiological and Metal COPCs: Sitewide and Property-Specific Evaluations across All Properties (EPC Tables K-2A and K-2B) include:

- incidental ingestion of inaccessible soil (ground cover absent),
- dermal contact with inaccessible soil (ground cover absent) (metals only),
- inhalation of particulate dust emissions from inaccessible soil (ground cover absent), and
- external gamma exposures from inaccessible soil (ground cover absent).

Table K-1 shows that the industrial worker scenario was applied to a total of 28 properties. In the current scenario, the HHRA assumes ground cover consisting of soil, the cover depth (i.e., the thickness of ground cover between the receptor and the top of the contaminated zone) of which is assumed to be 0.3048 m. In the future scenario, the HHRA assumes that property-wide inaccessible soil has become accessible, and that the cover depth is assumed to be 0 m. The current and future industrial workers are SLDS plant/VP employees assumed to work indoors 1,600 hours per year (200 days per year) and also perform light excavation/construction work outdoors for an additional 400 hours per year (50 days per year). An additional 125 hours is assumed for the indoor time fraction to account for the possibilities of early arrivals to work, having lunch on site, and late departures. Exposures to metal COPCs in inaccessible soil via ingestion, dermal contact, and inhalation of dusts can only occur during the fraction of time spent outdoors, or 50 days per year for 25 years for an industrial worker. Because of the levee material present at DT-2, DT-9, and DT-15, ground cover over inaccessible soil at these properties is assumed to be comprised of soil to a depth of 1 m for the industrial worker and recreational user, based on the shallowest radiological PRG exceedance. It is further assumed that the recreational user spends approximately 75 hours per year (i.e., 1 hour per day for 75 days), for 9 years, engaged in recreational activities at the St. Louis Riverfront Trail.

The assumption of 0 m for a cover depth is also assumed for the current/future construction worker and utility worker, because these receptors are exposed to inaccessible soil in open excavations. The durations assumed for the contact-intensive soil exposures for the construction worker and utility worker are 90 days and 10 days, respectively, for 1 year.

Soil exposure assumptions for the industrial worker, recreational user, construction worker, and utility worker are presented for radiological and metals evaluations in Tables K-6 and K-8, respectively.

K2.3.2.2 Soil on Surfaces of Buildings and Structures

Industrial workers working indoors can be exposed to radiological soil COPCs on interior surfaces of buildings. These exposures are assumed to occur 8 hours per day, 250 days per year, for 25 years, during the course of carrying out job responsibilities. During exterior maintenance or renovation/demolition activities, industrial maintenance workers could directly contact and become exposed to radiologically contaminated soil on exterior building or structural surfaces. Potential exposures to these surfaces are assumed to occur throughout the duration of a typical maintenance activity, which is assumed to be a once-in-a-lifetime event for an industrial worker (SLDS/VP employee), lasting for 10 days.

The HHRA scenarios for evaluating current/future industrial and maintenance worker exposures to radiological COPCs in soil on contaminated interior and exterior building surfaces is summarized in the following list.

Current/Future Industrial Worker Exposures to Radiological COPCs on Interior Building Surfaces (Table K-3B) include:

- incidental ingestion of soil on building surfaces,
- inhalation of particulate dust emissions from building surfaces, and
- external gamma exposures.

Current/Future Industrial (Maintenance) Worker Exposures to Radiological COPCs on Exterior Building Surfaces (Table K-3C) include:

- incidental ingestion of soil on building surfaces,
- inhalation of particulate dust emissions from building surfaces, and
- external gamma exposures.

Radiological dose and risk for buildings were calculated by entering the surface EPC and the exposure assumptions into the RESRAD-BUILD model. All exposure assumptions used as model inputs are presented in Table K-7.

K2.3.2.3 Sediment in Sewer Lines

During infrequent maintenance work on the interiors of manholes and sewer lines (assumed to be 1 day per year over 25 years), the potential exists for ingestion and dermal exposures to sewer maintenance workers to COPCs in sediment. Inhalation exposures to sediments are not likely to occur via the generation of particulate emissions from mechanical disturbance of the sediment during inside maintenance work activities because of the high moisture content that is characteristic of sediment. Exposure to infiltrating ground water could potentially occur but is unlikely and was not assessed during the HHRA. The HHRA scenario for evaluating sewer maintenance worker exposures to radiological and metal COPCs in sewer sediment is summarized in the following list.

Current/Future Sewer Maintenance Worker Exposures to Radiological and Metal COPCs in Sediments Inside of Sewer Lines (Tables K-4A and K-4B) include:

- incidental ingestion of sediment in sewers,
- dermal contact with contaminated sediment in sewers, and
- external gamma exposures.

All exposure assumptions for radiological and metals exposures for this receptor are presented in Tables K-6 and K-8, respectively.

K2.3.2.4 Soil Adjacent to Sewer Lines

The exposure scenario used for evaluating soil adjacent to sewer lines assumes that direct contact with this medium can occur to individuals only when excavation is performed (e.g., during removal/replacement of sewer lines). During an excavation scenario, the sewer utility worker is assumed to be the most exposed individual to small localized areas of inaccessible soil. This receptor is assumed to perform work specifically on the outside of lines, usually within a deep excavation, for a short duration (80 hours or 8 hours per day for 10 days). Therefore, the HHRA scenario for evaluating sewer utility worker exposures to radiological and metal COPCs in soil adjacent to sewer lines is summarized in the following list.

Current/Future Sewer Utility Worker Exposures to Radiological and Metal COPCs in Soil Adjacent to Sewer Lines (Tables K-5A and K-5B) include:

- incidental ingestion of soil adjacent to sewer lines,
- dermal contact with soil adjacent to sewer lines,

- inhalation of particulate dust emissions from excavated soil adjacent to sewer lines, and
- external gamma exposures from soil adjacent to sewer lines.

Assumptions and RESRAD model inputs used for evaluating sewer utility worker exposures to radiological and metal COPCs in inaccessible soil adjacent to sewer lines are presented in Tables K-6 and K-8, respectively. Lead in inaccessible soil adjacent to sewer lines was assessed using the ALM. The ALM is a biokinetic model that predicts the relative increase in PbB that might result from an environmental exposure. The ALM is used in this HHRA to predict the risk of elevated PbBs in non-residential settings (adult exposure to soil; ultimate receptor is fetus). In accordance with the USEPA's ALM methodology (USEPA 2003b), the mean soil concentration was used as the EPC for input into the ALM. Further explanation of the ALM and the results are presented in Sections K2.4.2.5 and K2.5.3.9, respectively.

K2.3.3 Methodology for Quantifying Dose

The magnitude of human exposure to contaminants in environmental media is usually described in terms of a dose. Radiological dose is a measure of the radiation absorbed by the body based on radionuclide concentrations and different intake pathways (ingestion, inhalation, and external radiation) and is expressed as mrem/yr. Chemical dose (also referred to as "intake") is a measure of exposure expressed as the concentration of a constituent that has come in contact (via ingestion and dermal contact) with a receptor per unit body weight per unit of time (milligrams of chemical per kilogram body weight per day [mg/kg-day]). For quantifying exposures via inhalation of dusts, an exposure concentration (EC) is determined as the time-weighted average concentration ($\mu g/m^3$) derived from measured or modeled contaminant concentrations in air, adjusted based on the characteristics of the exposure scenario being evaluated (USEPA 2009b). Sections K2.3.3.1 and K2.3.3.2 describe the methodologies used for calculating dose and risk for radiological COPCs and chemical dose (i.e., intake) for metal COPCs.

K2.3.3.1 Estimation of Radiological Dose and Risk

RESRAD was used to calculate dose and risk to potential ISOU receptors from exposures to soil and sewer sediment. RESRAD-BUILD was used for determining risk and dose from exposures to contaminated building surfaces. RESRAD and RESRAD-BUILD are computer codes developed at Argonne National Laboratory (ANL) for the DOE to determine site-specific residual radiation guidelines and dose to on-site receptors at sites that are contaminated with radioactive materials. The use of RESRAD codes for modeling dose and risk has become an acceptable industry practice among prominent federal agencies, including the following examples:

- The USEPA used RESRAD in its "Reassessment of Radium and Thorium Soil Concentrations and Annual Dose Rates," which demonstrated the protectiveness of Uranium Mill Tailings Radiation Control Act soil criteria, and in its rulemaking for cleanup of sites contaminated with radioactivity.
- Seven U.S. Cabinet-level agencies including the USEPA, the DOE, the NRC, and the U.S. Department of Defense (DOD), functioning as the Interagency Steering Committee on Radiation Standards, formally accepted RESRAD-BIOTA.
- The USEPA was also a signatory to the 1998 ROD (USACE 1998a), which incorporated RESRAD evaluations, and is a participant in many other CERCLA actions utilizing RESRAD.

In accordance with Title 40 *CFR* Part 192, Subpart A, control of residual radioactive materials from inactive uranium processing sites shall be designed to be effective for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. Therefore, for inaccessible soils, radiological risk in this HHRA, as well as dose, has been assessed over a 1,000-year period. Tables K-6 and K-7 present values assigned to all relevant non-default RESRAD and RESRAD-BUILD input parameters, respectively.

K2.3.3.2 Pathway-Specific Dose Calculations for Exposures to Metal Contaminants of Potential Concern

Chemical dose is the amount of chemical that comes into contact with an exchange surface (e.g., skin, lungs, and gastrointestinal [GI] tract) and is absorbed into the body, averaged over the duration of exposure (for non-carcinogens) or a lifetime (for carcinogens). The magnitude of the dose is dependent on the body weight of the receptor. All doses determined for metal COPCs were based on chronic exposures (as opposed to subchronic exposures) or exposures that occur on a daily basis for at least 90 days. For ingestion exposures to contaminants in any environmental medium, dose is referred to as the chronic daily intake (CDI) (USEPA 1989a). For dermal exposures to contaminants, dose is referred to as the dermally absorbed dose (DAD) (USEPA 2004b). For inhalation exposures, recent USEPA RAGS, Volume I, Part F, methodology (USEPA 2009b) has been used in calculating time-weighted average concentrations, referred to as ECs, for contaminants adsorbed onto soil, and released into the air as airborne particulates (i.e., from wind-blown action or mechanical disturbance).

Based on the metal COPCs identified in inaccessible soil, sewer sediment, and inaccessible soil adjacent to sewer lines, as well as the receptor information discussed in Section K2.3.2, CDIs, DADs, and ECs were determined for metal COPCs in these media for the following receptor scenarios:

- Future industrial worker (SLDS/VP employee) exposed to metal COPCs in inaccessible soil across all of the SLDS, as well as at Plant 2, Plant 6, DT-10, the DT-9 Main Tracks, DT-12, Hall Street, Mallinckrodt Street, and Destrehan Street (the current industrial worker scenario is not applicable due to incomplete exposure pathways from the presence of ground cover);
- Current/future construction worker exposed to metal COPCs in inaccessible soil across all of the SLDS, as well as at Plant 2, Plant 6, DT-10, the DT-9 Main Tracks, DT-12, Hall Street, Mallinckrodt Street, and Destrehan Street;
- Current/future utility worker exposed to metal COPCs in inaccessible soil across all of the SLDS, as well as at Plant 2, Plant 6, DT-10, the DT-9 Main Tracks, DT-12, Hall Street, Mallinckrodt Street, and Destrehan Street;
- Current/future sewer maintenance worker exposed to metal COPCs in sediment inside of sewer lines across all of the SLDS, as well as at Plants 1, 2, and 6 and DT-8; and
- Current/future sewer utility worker exposed to metal COPCs in soil adjacent to sewer lines across all of SLDS, as well as at Plants 1, 2, and 6, Plant 7N/DT-12, and DT-8/DT-11.

The following sections present general dose equations used to evaluate receptor exposures to metal COPCs in inaccessible soil, sewer sediment, and soil adjacent to sewer lines. The following inhalation equations are applicable to soil only, as this pathway is considered to be incomplete for sediment, because releases of sediment particulates into the air are prevented by the high percent moisture content of the sediment. Table K-8 summarizes all receptor-specific exposure parameters used as input values into the dose equations, which includes parameter descriptions, units, numerical values assigned to the parameters, and sources/rationale for the numerical values. Additional subscripting is applied in Table K-8 to the general parameters presented in the equations below to correlate inputs with receptor-specific scenarios.

The following equations are not applicable to exposures to lead in soil adjacent to sewer lines, because this was assessed, as previously stated, using the USEPA's ALM.

Non-Carcinogenic Exposures to Soil or Sewer Sediment via Incidental Ingestion

The CDI for a worker exposed to non-carcinogenic metal COPCs via the incidental ingestion of soil or sediment (CDI_{nc}) was calculated with the following formula (USEPA 1989a)

$$CDI_{nc} = \frac{C_s \times IR \times CF \times FI \times EF \times ED}{BW \times AT_{nc-ing}}$$

where:

$CDI_{nc} =$ chronic daily intake for worker exposures to non-carcinogenic metals in soil or sediment (mg/kg-day),

$C_s =$ metal concentration in soil or sediment (mg/kg),

$IR =$ soil or sediment ingestion rate (mg/day),

$CF =$ conversion factor (1.0E-06 kilograms per milligram [kg/mg]),

$FI =$ fraction of soil or sediment ingested from contaminated source (unitless),

$EF =$ soil or sediment exposure frequency (days/year),

$ED =$ exposure duration (years),

$BW_a =$ adult body weight (kg),

$AT_{nc-ing} =$ non-carcinogenic averaging time for soil or sediment ingestion exposures (days).

Non-Carcinogenic Exposures to Soil or Sewer Sediment via Dermal Contact

The DAD for a worker exposed to non-carcinogenic metal COPCs via dermal contact (DAD_{nc}) with soil or sediment was calculated with the following formula (USEPA 2004b)

$$DAD_{nc} = \frac{C_s \times CF \times SA \times AF \times ABS \times EF \times ED \times EV}{BW \times AT_{nc-derm}}$$

where:

$DAD_{nc} =$ dermally absorbed dose for worker exposures to non-carcinogenic metals in soil or sediment via dermal contact (mg/kg-day),

$C_s =$ metal concentration in soil or sediment (mg/kg),

$CF =$ conversion factor (1.0E-06 kg/mg),

$SA =$ skin surface area available for soil or sediment contact (cm^2),

$AF =$ skin adherence factor for soil or sediment contact (milligrams of chemical per square centimeter per event [mg/cm^2-event]),

$ABS =$ absorption factor (unitless),

$EF =$ soil or sediment exposure frequency (days per year),

$ED =$ exposure duration (years),

$EV =$ event frequency for soil contact (events per day),

$BW_a =$ adult body weight (kg),

$AT_{nc-derm} =$ non-carcinogenic averaging time for dermal exposures to soil or sediment (days).

Non-Carcinogenic Exposures to Soil via Dust Inhalation

The EC for a worker exposed to non-carcinogenic soil COPCs via the inhalation of airborne particulates emanating from inaccessible soil areas (EC_{nc}) was calculated with the following equation (USEPA 2009b)

$$EC_{nc} = \frac{C_s \times (PEF)^{-1} \times ET \times EF \times ED}{AT_{nc-inh}}$$

where:

$EC_{nc} =$ air exposure concentration for worker exposures to non-carcinogenic metals in soil particulates/dusts (micrograms per cubic meter [$\mu g/m^3$]),

$C_s =$ metal concentration in soil ($\mu g/m^3$),

$PEF =$ particulate emission factor (kilograms per cubic meter [kg/m^3]),

$ET =$ soil exposure time (hours per day),

$EF =$ soil exposure frequency (days per year),

$ED =$ exposure duration (years),

$AT_{nc-inh} =$ non-carcinogenic averaging time for inhalation exposures to airborne soil particulates/dusts (hours).

Carcinogenic Exposures to Soil or Sewer Sediment via Incidental Ingestion

The CDI for a worker exposed to carcinogenic metal COPCs via the incidental ingestion of soil or sediment (CDI_c) was calculated with the following formula (USEPA 1989a)

$$CDI_c = \frac{C_s \times IR \times CF \times FI \times EF \times ED}{BW \times AT_{c-ing}}$$

where:

$CDI_c =$ chronic daily intake for worker exposures to carcinogenic metals in soil or sediment (mg/kg-day),

$C_s =$ metal concentration in soil or sediment (mg/kg),

$IR =$ soil or sediment ingestion rate (mg/day),

$CF =$ conversion factor (1.0E-06 kg/mg),

$FI =$ fraction of soil or sediment ingested from contaminated source (unitless),

$EF =$ soil or sediment exposure frequency (days per year),

$ED =$ exposure duration (years),

$BW_a =$ adult body weight (kg),

$AT_{c-ing} =$ carcinogenic averaging time for soil or sediment ingestion exposures (days).

Carcinogenic Exposures to Soil or Sewer Sediment via Dermal Contact

The DAD for a worker exposed to carcinogenic metal COPCs via dermal contact with soil or sediment (DAD_c) was calculated with the following formula (USEPA 2004b)

$$DAD_c = \frac{C_s \times CF \times SA \times AF \times ABS \times EF \times ED \times EV}{BW \times AT_{c-derm}}$$

where:

$DAD_c =$ dermally absorbed dose for worker exposures to carcinogenic metals in soil or sediment via dermal contact (mg/kg-day),

$C_{sl} =$ metal concentration in soil or sediment (mg/kg),

$CF =$ conversion factor (1.0E-06 kg/mg),

$SA =$ skin surface area available for soil or sediment contact (cm^2),

$AF =$ skin adherence factor for soil or sediment contact (mg/cm^2-event),

$ABS =$ absorption factor (unitless),

$EF =$ soil or sediment exposure frequency (days per year),

$ED =$ exposure duration (years),

$EV =$ event frequency for soil or sediment contact (events per day),

$BW_a =$ adult body weight (kg),

$AT_{c-derm} =$ carcinogenic averaging time for dermal exposures to soil or sediment (days).

Carcinogenic Exposures to Soil via Dust Inhalation

The EC for a worker exposed to carcinogenic soil COPCs via the inhalation of airborne particulates emanating from inaccessible soil areas (EC_c) was calculated with the following equation (USEPA 2009b)

$$EC_c = \frac{C_s \times (PEF)^{-1} \times ET \times EF \times ED}{AT_{c-inh}}$$

where

$EC_c =$ air exposure concentration for worker exposures to non-carcinogenic metals in soil particulates/dusts ($\mu g/m^3$),

$C_s =$ metal concentration in soil (μg/m³),

$PEF =$ particulate emission factor (kg/m³),

$ET =$ soil exposure time (hours per day),

$EF =$ soil exposure frequency (days per year),

$ED =$ exposure duration (years),

$AT_{c-inh} =$ carcinogenic averaging time for inhalation exposures to airborne soil particulates/dusts (hours).

K2.4 TOXICITY ASSESSMENT

The toxicity assessment identifies the chemical-specific toxicity values (e.g., cancer slope factors [CSFs] and reference doses [RfDs]) for COPCs identified in ISOU media. These toxicity values were applied to the estimated doses (intakes) to quantify carcinogenic and non-carcinogenic risks. For radiological evaluations, the source of slope factors (SFs) used in the RESRAD and RESRAD-BUILD evaluations is Federal Guidance Report (FGR) 13 (USEPA 1999c).

In accordance with the hierarchy of sources established by the USEPA for obtaining chemical toxicity values for metal COPCs (USEPA 2003a), USEPA's *Integrated Risk Information System* (IRIS) (USEPA 2012b) was used as the preferred source. The IRIS website is continuously updated to reflect the latest toxicological information that is currently available and derived from the results of studies recognized by the USEPA as being of a sufficient degree of confidence for use in risk assessments. The USEPA recommends the following three-tiered hierarchy of toxicological data sources from which to select toxicity criteria:

- Tier 1 – USEPA's on-line IRIS database;
- Tier 2 – Provisional Peer-Reviewed Toxicity Values derived by USEPA's Superfund Health Risk Technical Support Center for the Superfund program; and
- Tier 3 – Other toxicity criteria as recommended by USEPA's National Center for Environmental Assessment, such as the California Environmental Protection Agency, the Agency for Toxic Substances and Disease Registry, or the *Health Effects Assessment Summary Tables* (USEPA 1995b).

K2.4.1 Radiological Toxicity Assessment

Health impacts from exposure to radiation and radionuclides are expressed as the risk of developing cancer and have been determined using the RESRAD computer code. Because radiological exposures may result in cancer, CRs from exposures to ISOU radiological PCOCs have been estimated using USEPA SFs developed for inhalation, ingestion, and external radiation exposure routes. The radiological SFs specific to each exposure route are used to convert exposure to CR.

All radiological SFs used in this ISOU BRA are presented in Table K-9. SFs for radionuclides are defined differently than SFs for metals. The USEPA outlines these differences in the *Radiation Exposure and Risk Assessment Manual* (USEPA 1996b). Major differences include the following:

- The SFs for radiological COPC are based on the endpoint of morbidity – the endpoint for metal exposures is tumorigenic cancer or non-carcinogenic risk.

- Radiological risk estimates are based primarily on human data – metals risk estimates are based primarily on animal studies and extrapolated to the human population.
- Radiological risk estimates are based on the central estimate of the mean – metals risk estimates are based on the 95 percent UCL of the mean.

A dose conversion factor for radiological exposures was used to calculate lifetime committed effective dose equivalents. Radiological doses were calculated to ensure compliance with ARARs to be identified for radiological contamination. For a site to be released for unrestricted use, Title 10 *CFR* Part 20, Subpart E, requires the radiological dose to be less than 25 mrem/yr, which is approximately equivalent to a CR of 5.0E-04 (USEPA 1997a). The appropriate dose limit will be determined during ARARs development in the FS.

K2.4.2 Toxicity Assessment for Metals

The following sections discuss and present information relevant to the evaluation of toxicities of the metal COPCs identified in ISOU media. All numerical toxicity criteria and information for metal COPCs are presented in Tables K-10A through K-10C, with the following information being presented for each PCOC, as appropriate: weight-of-evidence classification, tumor site(s), unit risk values, uncertainty factors, modifying factors, and non-carcinogenic target organs/critical effects.

K2.4.2.1 Cancer Toxicity Assessment for Metal Contaminants of Potential Concern

USEPA SFs used for estimating CRs for metal compounds are upper 95th percentile confidence limits of the probability of response per unit intake (by oral or inhalation routes) over a lifetime. SFs for metals are based on mathematical extrapolation from experimental animal data and epidemiological studies, when available. SFs are expressed in units of risk per milligrams per kilogram body weight per day ([mg/kg-day]$^{-1}$). Because SFs are upper-bound estimates, actual cancer potency of PCOCs are likely lower than estimated (USEPA 1989a).

K2.4.2.2 Non-cancer Toxicity Assessment for Metal Contaminants of Potential Concern

The RfD is an exposure route-specific estimate of a daily intake per unit body weight that is likely to be without deleterious effects (USEPA 1989a). The USEPA derives RfDs to protect sensitive populations, such as children, and has developed many chronic RfDs to evaluate long-term exposures (7 years to a lifetime) and a few subchronic RfDs to evaluate exposures of shorter duration (2 weeks to 7 years).

K2.4.2.3 Dermal Toxicity Assessment for Metal Contaminants of Potential Concern

There are no toxicity values specific to dermal exposure; therefore, the USEPA recommends that oral toxicity values be adjusted to assess risks from dermal exposure. The approach is described in the USEPA guidance document RAGS, Volume 1, Part E (USEPA 2004b). The oral toxicity factor for a metal relates toxic response to an administered dose of only some metals, which may be absorbed by the body; whereas, intake from dermal contact is estimated as an absorbed dose using chemical-specific permeability constants for absorption from water and dermal-absorbed fraction from soil (USEPA 2004b). To ensure that dermal toxicity is not underestimated, the USEPA recommends adjusting oral toxicity factors by chemical-specific GI absorption fractions (GIABS) to evaluate toxic effects of a DAD (USEPA 2004b). Oral RfDs (RfD_o) are adjusted to derive dermal RfDs (RfD_d) using the following equation:

$$RfD_d = RfD_o \times GIABS$$

Oral SFs (SF_o) are adjusted to derive dermal SFs (SF_d) using the following equation:

$$SF_d = \frac{SF_o}{GIABS}$$

GI absorption efficiencies vary widely for inorganic compounds. Of the metal COPCs identified at the SLDS, GI absorption efficiencies are available for arsenic and cadmium. The GI absorption efficiency for arsenic is estimated to be 95 percent, so no adjustment of the toxicity factor is recommended. The GI absorption efficiency for cadmium is estimated to be between 2.5 and 5 percent, so adjustment of the toxicity factor is recommended. Lead it was assessed using the ALM, so no adjustment was needed.

K2.4.2.4 Inhalation Toxicity Assessment for Metal Contaminants of Potential Concern

USEPA guidance for evaluating the inhalation exposure pathway (RAGS, Volume I, Part F [USEPA 2009b]) recommends the use of carcinogenic inhalation unit risk (IUR) and non-carcinogenic reference concentration (RfC) values.

The IUR is defined as the upper-bound excess lifetime CR estimated to result from continuous exposure to an agent at a concentration of 1 micrograms/meter cubed ($\mu g/m^3$) in air. IURs are expressed in units of cubic meters per milligram of chemical $(mg/m^3)^{-1}$.

The inhalation RfC is defined as an estimate of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to not result in a significant risk of systemic effects during a lifetime. Estimates of RfCs are associated with uncertainty spanning approximately an order of magnitude. The RfC can be derived from a no observed adverse effects level (NOAEL), a lowest observed adverse effects level (LOAEL), or benchmark concentration. Various types of RfCs are available depending on the type of critical effect and the length of exposure being evaluated (chronic or subchronic).

K2.4.2.5 Toxicity Assessment for Lead

Lead is classified as a B2 carcinogen, and it has known non-carcinogenic effects; however, no toxicity values have been established for lead. The USEPA regulates lead exposure using a biomarker (PbB), which can be estimated using the ALM. The ALM is a biokinetic model that predicts the relative increase in PbB that might result from an environmental exposure. The ALM can be used to predict the risk of elevated PbBs in a non-residential setting (adult exposure to soil; ultimate receptor is fetus).

Biokinetic models work best when there is a known effect that is associated with a specific tissue concentration in humans. For lead, that effect is impaired nerve conduction velocity in children at 10 µg Pb/dL blood. The CDC established 10 µg Pb/dL blood as the federal level of concern in 1991, and the USEPA's OSWER risk reduction policy calls for no child to have greater than a 5 percent probability of having a PbB >10 µg/dL. The basis for the ALM PRG calculation is the relationship between the soil lead concentration and the PbB in the developing fetus of adult women who have site exposures. The ALM describes the estimated relationship between the PbB in adult women and the corresponding 95th percentile fetal PbB, assuming that PbBs in women of child-bearing age reflect the geometric mean of a lognormal distribution.

Default values for the ALM input parameters were originally derived from an analysis of blood lead data for U.S. women 17 to 45 years of age, from Phase I (1988 to 1991) of the Third National Health and Nutrition Examination Survey (NHANES III) as well as consideration of available site-specific data on PbBs. For the SLDS, the ALM used updated estimates for the geometric standard deviation of blood level (GSD_i) and baseline PbB based on data from the NHANES surveys that were conducted from 1999 to 2004. In addition to soil lead concentrations, site-specific values incorporated into the ALM runs include soil ingestion rate and frequency of exposure. The ALM default value for soil ingestion is 50 mg/day. Because soil adjacent to sewers is most likely to be disturbed by a utility worker with fairly high exposure to soil, the ALM was run with a soil ingestion rate of 480 mg/day. Utility workers are likely to have fairly high exposure to soil; however, their frequency of exposure was assumed to be intermittent, 10 days per year, as opposed to the default exposure frequency of 219 days per year for an industrial worker.

K2.5 DOSE AND RISK CHARACTERIZATION

The objective of risk characterization is to integrate the information developed in the exposure assessment and the toxicity assessment into an evaluation of the potential current and future health risks associated with radiological and metal COPCs. In this step, the toxicity factors (SFs and RfDs) are applied in conjunction with dose to estimate potential carcinogenic health risks (radiological and metal COPCs) and non-carcinogenic hazards (metal COPCs). Sections K2.5.1 and K2.5.2 describe how the carcinogenic and non-carcinogenic risk calculations were performed, respectively. Determination of CR from exposures to radiological contamination in inaccessible soil and on building surfaces was performed using the RESRAD (Version 6.5) and RESRAD-BUILD (Version 3.5) models, respectively. Attachment O-1 of Appendix O and Appendix P present RESRAD and RESRAD-BUILD output files, respectively, from the radiological dose and risk evaluations of all receptors under the assumptions of industrial land use. Attachment Q-1 of Appendix Q presents risk calculation spreadsheets for evaluating exposures to arsenic and cadmium in soil for all receptors under the assumptions of industrial land use. Attachment Q-2 of Appendix Q presents ALM spreadsheets for evaluating adult worker exposures to lead in soil adjacent to sewers.

K2.5.1 Estimation of Carcinogenic Risk from Radiological and Metal Exposures

The potential for carcinogenic effects was characterized in terms of the incremental probability of an individual developing cancer over a lifetime as a result of site-related exposure to a potential carcinogen. CRs for radiological COPCs were estimated based on SFs that reflect morbidity. For metals, excess lifetime CRs were estimated from the projected lifetime daily average intake and the carcinogenic SF or IUR, which represents an upper-bound estimate of the dose-response relationship.

Generally, excess lifetime CR for carcinogenic effects is calculated by multiplying the estimated dose (i.e., lifetime-averaged daily intake for metals, and average annual dose for radionuclides) via an exposure route by the exposure route-specific (oral, inhalation, dermal, or external radiation) carcinogenic SF or IUR, as described as follows

$$CR = Dose \times Toxicity\ Value$$

where:

CR	=	Cancer risk (unitless);
$Dose$	=	Oral CDI (mg/kg-day), DAD (mg/kg-day), or air EC (µg/m^3) for inhalation; and
$Toxicity\ Value$	=	Oral or dermally adjusted cancer SF_o or SF_d, ([mg/kg-day]$^{-1}$) or IUR (µg/m^3).

The CRs resulting from exposure to multiple carcinogens are assumed to be additive. However, because SFs and IURs for radionuclides and metals are specific to distinct models that incorporate different assumptions (as indicated previously), the USEPA's RAGS, Volume I, Part A, guidance cautions against combining (i.e., summing) radiological CRs with metal CRs (USEPA 1989a). In addition, natural background radiation is ubiquitous at levels exceeding typical risk targets, and natural variability may preclude the ability to quantify small incremental CRs due to contamination. Therefore, total CRs to be calculated for radiological and metal COPCs are assessed separately and are not summed together for estimation of cumulative CRs.

USEPA policy must be considered to interpret the significance of the CR estimates. In the NCP (USEPA 1990), the USEPA states that for known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper-bound lifetime CR of between 1.0E-06 and 1.0E-04 (i.e., USEPA's target CR range).

K2.5.2 Estimation of Non-Carcinogenic Hazard for Metal Exposures

The potential for non-carcinogenic health effects resulting from exposures to individual metal COPCs was evaluated by the calculation of an HQ. An HQ is the ratio of the exposure duration-averaged estimated daily intake through a given exposure route, to the chemical and route-specific (i.e., oral, inhalation, or dermal) RfD or RfC, calculated as follows

$$HQ = \frac{Dose}{Toxicity\ Value}$$

where:

HQ = hazard quotient (unitless);
$Dose$ = Oral CDI (mg/kg-day), or DAD (mg/kg-day), or air EC (μg/m^3) for inhalation;
$Toxicity\ Value$ = Oral or dermally adjusted RfD_o or RfD_d, (microgram of chemical per kilogram body weight per day [μg/kg-day]) or inhalation RfC (mg/m^3).

Use of the RfD or RfC assumes that there is a level of intake (the RfD or RfC) below which it is unlikely that even sensitive individuals, such as children, will experience adverse health effects over the period of exposure. If the average daily intake exceeds the RfD or RfC (i.e., if the HQ exceeds 1.0), then there may be cause for concern for potential non-cancer, systemic effects (USEPA 1989a). It should be noted, however, that the level of concern does not increase linearly as the RfD or RfC is approached or exceeded. Because the HQ does not define a dose-response relationship, its numerical value cannot be construed as a direct estimate of risk (USEPA 1989a). Rather, an HQ greater than 1.0 indicates a potential cause for concern for non-cancer health effects, which might indicate the need for re-evaluating actual exposure conditions or concentrations or consideration of risk management alternatives.

To assess pathway-specific exposures to multiple metals, the HQs over all metal COPCs are summed to yield an HI. The assumption of additive effects reflected in the HI is most properly applied to substances that induce the same effect by the same biological mechanism (USEPA 1989a). Consequently, summing HQs for substances that are not expected to induce the same type of toxic effect will overestimate the potential for adverse health effects. The HI provides a measure of the potential for adverse effects, but it is conservative and dependent on the quality of experimental evidence.

If a receptor is exposed by multiple pathways, then the HIs from all relevant pathways are summed to obtain the total HI for that receptor. If the total HI is less than or equal to 1.0, then multiple-pathway exposures to COPCs at the site will be judged unlikely to result in an adverse effect. If the total HI is greater than 1.0 then further evaluation of exposure assumptions and toxicity, including consideration of specific target organs affected and mechanisms of toxic actions of COPCs, are warranted to ascertain if the cumulative exposure would, in fact, be likely to harm exposed individuals. However, given that arsenic and cadmium are the only two metal COPCs being evaluated, and they affect different target organs, the evaluation of target organs and critical effects was not necessary in this HHRA.

K2.5.3 Determination of Area-Weighted Average Doses and Risks for Combined Inaccessible and Accessible Soil Evaluations

Combined inaccessible and accessible soil evaluations of dose and risk are conducted for the sitewide and property-specific industrial worker scenarios. Similarly, combined inaccessible and accessible soil evaluations of dose and risk are conducted for the recreational user scenarios, though the evaluations are limited to the three properties (DT-2, DT-9 Levee and DT-15) containing the St. Louis Riverfront Trail, which runs along the levee. The recreational user is evaluated for dose and risk under property-specific scenarios as well as for dose and risk for all three properties combined.

For both the industrial worker and recreational user, dose and risk are each calculated as the weighted average between the inaccessible soil area and the accessible soil area for each sitewide and property-specific evaluation. Area-weighted averaging is being applied to dose and risk, rather than to EPCs, because the area-weighting of EPCs does not allow for a means by which ground cover can be applied to inaccessible area soils, while not applying it to accessible area soils, in the RESRAD model. The inaccessible and accessible sampling locations and data for all properties evaluated are presented in figures and tables in Appendices E and L, respectively. In all figures within both appendices, the inaccessible soil areas are presented as the cross-hatched areas. The following equation is used for calculating area-weighted averages of radiological dose for each sitewide and property-specific scenario:

$$Dose_{AW=}\frac{(Dose_I \times Area_I) + (Dose_A \times Area_A)}{Area_T}$$

where:

$Dose_{AW}$	=	area-weighted average radiological dose (mrem/yr);
$Dose_I$	=	radiological dose for inaccessible area (mrem/yr);
$Dose_A$	=	radiological dose for accessible area (mrem/yr);
$Area_I$	=	size of inaccessible area (m^2);
$Area_A$	=	size of accessible area (m^2); and
$Area_T$	=	size of total area (sum of inaccessible and accessible areas) (m^2);

The following equation is used for calculating area-weighted averages of risk (i.e., radiological CR, metal CR, or metal HI) for each sitewide and property-specific scenario:

$$Risk_{AW=}\frac{(Risk_I \times Area_I) + (Risk_A \times Area_A)}{Area_T}$$

where:

$Risk_{AW}$	=	area-weighted average of radiological CR, metal CR or metal HI (unitless)

$Risk_I$	=	radiological CR, metal CR or metal HI for inaccessible area (unitless);
$Risk_A$	=	radiological CR, metal CR or metal HI for accessible area (unitless);
$Area_I$	=	size of inaccessible area (m^2);
$Area_A$	=	size of accessible area (m^2); and
$Area_T$	=	size of total area (sum of inaccessible and accessible areas) (m^2);

K2.5.4 Risk and Dose Characterization of the Inaccessible Soil Operable Unit

Sections K2.5.4.1 through K2.5.4.9 describe the medium- and property-specific radiological and metal dose and risk results, estimated by receptor scenario, which have been determined for the SLDS ISOU. During characterization discussions, comparisons are made versus the target dose of 25 mrem/yr, USEPA's target CR range, and the target HI of 1.0; however, the characterization is only a presentation of dose and risk results and aforementioned comparisons do not constitute judgments being made with respect to the need for action. Only those dose and CR values that exceed the target dose and the USEPA's target CR range are presented in text in Sections K2.5.4.1 through K2.5.4.9 (no exceedances of the target HI occur for any of the evaluated scenarios).

All radiological and metals doses and risks estimated for SLDS background soil and sewer sediment are presented for each receptor scenario in Tables K-11A and K-11B, respectively. The maximum total radiological doses and risks for all sitewide and property-/location-specific receptor scenarios, including the corresponding maximum total background dose and risk, that occur over the 1,000-year evaluation period, are presented in Tables K-12, K-13A, K-14, K-15A, K-16A, K-17, K-18, K-19A, and K-20A. These tables show dose above background (i.e., background dose is subtracted from the site dose), as well as CRs both with and without background risk. Doses and CRs are presented above background for consistency with the work being conducted under the 1998 ROD at the same properties being evaluated for ISOU-related doses and CRs. In Sections K2.5.4.1 through K2.5.4.9, all discussions of dose pertain to dose above background. As stated previously, the background doses and CRs for soil and sediment are estimated using the BVs as EPCs. Because the BVs are 95 percent UCLs derived from ranges of measured background concentrations, there are many instances of site doses and risks estimated as being within or less than the corresponding background doses and risks, which are indicated in the tables by "<BKGD." RESRAD and RESRAD-BUILD model outputs for all scenarios are presented in Appendices O and P, respectively.

The CRs and HIs estimated for metals for all sitewide and property-/location-specific receptor scenarios, including the corresponding background CRs and HIs, are presented in Tables K-13B, K-15B, K-16B, K-19B, K-20B, and K-20C. Unlike the radiological dose and risk characterization tables, only CRs and HIs inclusive of background are being presented for metals for consistency with CERCLA methodology, which are then qualitatively compared to background CRs and HIs estimated for the corresponding receptor scenarios. Similar to the radiological doses and CRs, there are numerous instances in which site CRs and HIs are within or less than the ranges of background. Site CRs and HIs for metals that exceed corresponding background are shaded in the tables. All risk calculation spreadsheets are presented in Attachment Q-1 of Appendix Q for metals and in Attachment Q-2 of Appendix Q for lead (i.e., ALM model results). All SLDS doses and risks below corresponding background doses and risks are also noted in the tables.

For the purpose of discussion, the two industrial/commercial VP groupings (South of Angelrodt and West of Broadway Property groups) are discussed in the following subsections as "properties," along with the individual properties, because the two VP groupings are assessed as single properties. Additionally, all eight roadways are considered to be comprised of only inaccessible soil areas, so combined inaccessible and accessible exposures for the industrial worker are not evaluated.

Finally, as discussed previously, a hypothetical resident gardener scenario was evaluated but is presented separately, in Attachments K-1 and K-2 to this appendix. This is because current land use is predominantly industrial/commercial, and land use is expected to remain as such for the foreseeable future; therefore, it is recommended that scenarios assuming industrial land use be used as the basis for determining future actions at the ISOU. The hypothetical resident gardener was evaluated as an unlimited use and unrestricted exposure scenario for only informational purposes to facilitate future decision making as needed. As discussed in Attachment K-1, weight-of-evidence considerations generally suggest that doses and risks estimated for a resident gardener scenario represent overestimations of actual doses and risks associated with inaccessible soil.

K2.5.4.1 Current Industrial Worker Exposures to Radiological COPCs in Inaccessible Soil and Combined Inaccessible and Accessible Soil at All Properties

Table K-12 presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for sitewide and property-specific inaccessible soil exposures to current industrial workers. Property-specific scenarios were evaluated over 28 SLDS properties (4 plant properties, 10 industrial/commercial VPs, 6 RR VPs, and 8 roadways). Inaccessible soil dose and risk were calculated assuming a 0.3-m-thick soil cover is in place. Additionally, combined inaccessible and accessible soil dose and risk were calculated under the assumption of ground cover being present in all inaccessible soil areas and no ground cover being present in the accessible soil areas. The risk and dose for the combined inaccessible and accessible soil areas were calculated as area-weighted averages of the risks and doses estimated for the inaccessible and accessible areas, in order to calculate property-wide risk estimates. The current industrial worker was not evaluated for health risks associated with metal COPCs in inaccessible soil, because there are no complete exposure pathways for metal COPCs due to the presence of ground cover.

For inaccessible soil, the maximum total radiological sitewide dose, as well as the maximum total dose estimates for all 28 properties, are less than the target criterion of 25 mrem/yr. The maximum total radiological CRs estimated for inaccessible soil sitewide, as well as for 25 of the total 28 properties evaluated, are either within or exceed the USEPA's target CR range. The St. Louis Riverfront Trail properties (DT-2, DT-9 Levee, and DT-15) are the only three properties for which CRs are estimated to be less than USEPA's target CR range. CR estimates for inaccessible soil are greatly reduced when considering only CRs above background. Most inaccessible soil CRs above background are within USEPA's target range. However, the inaccessible soil CRs above background estimated for Plant 2 and DT-34 are less than the target CR range for the current industrial worker.

Radiological dose and risk for combined inaccessible and accessible soil was assessed both sitewide and at 20 properties. The eight roadways were not evaluated for combined inaccessible and accessible soil exposures because these areas consist only of inaccessible soil. The maximum total sitewide dose and the maximum total dose estimates for all 20 properties, are less than the target criterion of 25 mrem/yr. The maximum total CRs estimated for combined inaccessible and accessible soil for the sitewide scenario, as well as for the CRs estimated for all 20 of the evaluated property-specific scenarios, are either within or exceed the USEPA's target CR range. CR estimates for combined inaccessible and accessible soil are reduced when considering only CRs above background, with all CRs above background estimated as being within USEPA's target range.

The current industrial worker was not evaluated for health risks associated with inaccessible soil exposures to metals because of no complete direct contact pathways due to the presence of ground cover.

In summary, radiological maximum total dose estimates for inaccessible soil and property-wide soil (inaccessible and accessible soil combined) for all sitewide and property-specific scenarios evaluated are less than the target criterion of 25 mrem/yr. When considering inaccessible soil CRs above background, most CRs are within USEPA's target CR range, with those estimated for Plant 2 and DT-34 being less than the target range. Estimates of CRs above background for combined inaccessible and accessible soil are all CRs within USEPA's target range.

K2.5.4.2 Future Industrial Worker Exposures to Radiological and Metal COPCs in Inaccessible Soil and Combined Inaccessible and Accessible Soil at All Properties

Table K-13A presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for the sitewide and property-specific inaccessible soil exposures to current industrial workers. Property-specific scenarios were evaluated over 28 SLDS properties (4 plant properties, 10 industrial/commercial VPs, 6 RR VPs, and 8 roadways). For the future scenario, inaccessible soil dose and risk were calculated assuming that no ground cover is present. Additionally, combined inaccessible and accessible soil dose and risk were calculated under the assumption that ground cover is absent from both the inaccessible soil and accessible soil areas. The risk and dose for the combined inaccessible and accessible soil areas were calculated as area-weighted averages of the risks and doses estimated for the inaccessible and accessible areas, in order to calculate property-wide risk estimates.

For inaccessible soil, the maximum total radiological doses above background for Plant 1 (29 mrem/yr) and DT-4 North (45 mrem/yr) exceed the target criterion of 25 mrem/yr. The maximum total radiological CRs estimated for inaccessible soil for the sitewide scenario, as well as for 23 of the total 28 property-specific scenarios evaluated, exceed USEPA's target CR range. The inaccessible soil CRs for Mallinckrodt Security Gate 49 (8.4E-05) and DT-29 (9.4E-05) are within USEPA's target CR range. The inaccessible soil CRs for the 3 St. Louis Riverfront Trail properties are less than the target CR range.

Radiological dose and risk for combined inaccessible and accessible soil were assessed both sitewide and at 20 properties. None of the doses for these properties exceed 25 mrem/yr; for the future industrial worker, but the dose for one property (DT-4 North) is approximately equal to 25 mrem/yr. Of the 20 properties evaluated, the maximum total CR estimated for combined inaccessible and accessible soil for the sitewide scenario, as well as for the CRs estimated for 19 of the evaluated property-specific scenarios, exceed USEPA's target CR range. The combined inaccessible and accessible CR for DT-15 is within the target CR range. When considering combined inaccessible and accessible soil CRs above background, Plant 1 (2.5E-04), DT-4 North (4.4E-04), and DT-9 Rail Yard (3.1E-04) exceed the target CR range. The remainder of the combined inaccessible and accessible soil CRs above background are within the target range.

Table K-13B presents total CRs and non-carcinogenic HIs estimated for future industrial worker exposures to metal COPCs in inaccessible soil for the sitewide and 9 property-specific scenarios within the former uranium-ore processing boundary. The total CRs for all inaccessible soil scenarios are within USEPA's target CR range due to future industrial worker ingestion exposures to arsenic. The inaccessible soil CRs for Plant 2, Plant 6, DT-9 Main Tracks, and Hall Street are within the range of background. The HI values estimated for all future industrial worker exposures to inaccessible soil are less than the USEPA's target value of 1.0.

Total CRs and non-carcinogenic HIs were also estimated for future industrial worker exposures to metal COPCs in combined inaccessible and accessible soil sitewide and 6 property-specific scenarios (excluding the roadways) within the former uranium-ore processing boundary. The total CRs for all combined inaccessible/accessible soil scenarios are within USEPA's target CR range due to future industrial worker ingestion exposures to arsenic. All combined inaccessible/accessible soil CRs for the sitewide scenario and 6 property scenarios exceed background. The HI values estimated for all future industrial worker exposures to all combined inaccessible/accessible soil scenarios are less than the USEPA's target value of 1.0.

In summary, maximum total radiological dose estimates for future industrial worker exposures to inaccessible soil at Plant 1 (29 mrem/yr) and DT-4 North (45 mrem/yr) exceed the target criterion of 25 mrem/yr. When considering radiological inaccessible soil CRs above background, only the CRs estimated for Plant 1 (5.2E-04), Plant 6 (3.0E-04), DT-4 North (7.9E-04), and DT-6 (2.5E-04) exceed the target CR range. All remaining inaccessible soil CRs above background are within the target CR range. Combined radiological inaccessible and accessible soil CRs above background for Plant 1 (2.5E-04), DT-4 North (4.4E-04), and DT-9 Rail Yard (3.1E-04) exceed the target CR range. The remainder of the combined inaccessible and accessible soil CRs above background are within the target CR range.

For metals, the total CRs for all inaccessible soil scenarios are within USEPA's target CR range due to future industrial worker ingestion exposures to arsenic. The total CRs for all combined inaccessible/accessible soil scenarios are within USEPA's target CR range due to future industrial worker ingestion exposures to arsenic. All HI values estimated for all future industrial worker exposures to inaccessible soil, as well as to combined inaccessible and accessible soil, are less than the USEPA's target value of 1.0.

K2.5.4.3 Current/Future Recreational User Exposures to Radiological COPCs in Inaccessible Soil and Combined Inaccessible and Accessible Soil at DT-2, DT-9 Levee, and DT-15

The current/future recreational user was evaluated for radiological exposures assumed to occur in three properties (DT-2, DT-9 Levee, and DT-15) containing the St. Louis Riverfront Trail both combined and individually. Table K-14 presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for inaccessible soil exposures, as well as for combined inaccessible and accessible soil exposures, to current/future recreational users in the three properties. For the purpose of evaluating this receptor in the HHRA, the levee is assumed to be the ground cover that is always present in the inaccessible soil areas of these properties, at an assumed minimal thickness of 1 m. Accessible soil dose and risks are calculated under the assumption of no ground cover.

The maximum total radiological dose estimates for recreational user exposures to inaccessible soil at the three properties containing the St. Louis Riverfront Trail, both individually and combined, are all below the target criterion of 25 mrem/yr. The maximum total radiological CRs and the CRs above background estimated for inaccessible soil along the St. Louis Riverfront Trail within the three properties, both individually and combined, are all less than the USEPA's target CR range.

The maximum total radiological dose estimates for combined inaccessible/accessible soil for the three properties containing the St. Louis Riverfront Trail, both individually and combined, are all below the target criterion of 25 mrem/yr. However, the maximum total radiological CRs estimated for combined inaccessible/accessible soil for the combined three properties and for DT-2 and DT-9 Levee are within USEPA's target CR range. All estimates of CR above background for combined inaccessible/accessible soil for all property scenarios are less the target CR range.

The current/future recreational user was not evaluated for potential health risks associated with metal COPCs, because no metal COPCs were identified in inaccessible or accessible soil at any of the three properties containing the St. Louis Riverfront Trail.

In summary, maximum total radiological dose estimates for recreational user exposures to inaccessible soil, as well as to combined inaccessible/accessible soil, do not exceed the target criteria of 25 mrem/yr at any of the three properties evaluated, both separately and combined, that contain the St. Louis Riverfront Trail. All maximum total CRs above background estimated for inaccessible soil, as well as for the combined inaccessible/accessible soil, are less than the target CR range for all property scenarios.

K2.5.4.4 Current/Future Construction Worker Exposures to Radiological and Metal COPCs in Inaccessible Soil at All Properties

Table K-15A presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for inaccessible soil exposures to current/future construction workers. The dose and risk evaluations were conducted for a sitewide scenario, as well as for property-specific scenarios. For the property-specific scenarios, a total of 28 SLDS properties were evaluated, (4 plant properties, 10 industrial/commercial VPs, 6 RR VPs, and 8 roadways). It was assumed that ground cover currently in place over inaccessible soil is absent due to excavation/construction activities. This receptor is assumed to have one-time exposures to inaccessible soil at all investigated depths.

All total maximum radiological dose estimates for inaccessible soil exposures to the current/future construction worker are below the target criterion of 25 mrem/yr for the sitewide scenario and property-specific scenarios. The maximum total CRs for the sitewide and all 28 evaluated property-specific scenarios for the current/future construction worker are within USEPA's target CR range. However, when CRs above background are considered for inaccessible soil, only the CRs for Plant 1, Plant 6, DT-4 North, DT-6, DT-9 Rail Yard, Terminal RR Soil Spoils Area, Buchanan Street, and Hall Street are within the target CR range. All other CRs are less than the target CR range and/or background.

Table K-15B presents potential health risks estimated for current/future construction workers associated with exposures to metal COPCs in a sitewide inaccessible soil scenario and eight property-specific inaccessible soil scenarios. Both the sitewide and property-specific scenarios evaluated exposures within the former uranium-ore processing boundary. Total CRs for construction workers are within USEPA's target CR range for the sitewide scenario and two of the eight property-specific scenarios (DT-10 and DT-12). All other CRs are less than the target CR range and/or background. The predominant contributor to inaccessible soil risk for these properties is ingestion of arsenic. For the non-carcinogenic evaluations, the sitewide HI and all property-specific HIs are less than the target HI of 1.0.

In summary, evaluation of total maximum radiological dose above background results in all dose estimates for current/future construction worker exposures to inaccessible soil as being less than the target criterion of 25 mrem/yr for the sitewide scenario and all 28 property-specific scenarios. The maximum total radiological CR above background estimated for construction worker exposures results in the following properties being within USEPA's target CR range: Plant 1, Plant 6, DT-4 North, DT-6, DT-9 Rail Yard, Terminal RR Soil Spoils Area, Buchanan Street, and Hall Street. All other CRs are less than the target CR range and/or background. The total CRs above background estimated for construction worker exposures to metals in inaccessible soil are within USEPA's target CR range for DT-10 and DT-12 within the former uranium-ore processing boundary. All other CRs are less than the target CR range and/or background. The predominant contributor to inaccessible soil risk for these properties is ingestion of arsenic. For the non-carcinogenic evaluations, the sitewide HI and all property-specific HIs are less than the target HI of 1.0.

K2.5.4.5 Current/Future Utility Worker Exposures to Radiological and Metal COPCs in Inaccessible Soil at All Properties

Table K-16A presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for inaccessible soil exposures to current/future utility workers. The dose and risk evaluations were conducted for a sitewide scenario, as well as for property-specific scenarios. For the property-specific scenarios, a total of 28 SLDS properties were evaluated. It was assumed that ground cover currently in place over inaccessible soil is absent due to excavation. This receptor is assumed to have one-time exposures to inaccessible soil at all investigated depths where utilities could be present.

All total maximum radiological dose estimates for inaccessible soil exposures to the current/future utility worker are below the target criterion of 25 mrem/yr and/or background for both the sitewide scenario and the property-specific scenarios. The maximum total CRs estimated for the following property-specific utility worker scenarios are within USEPA's target CR range: Plant 1, DT-4 North, and DT-9 Rail Yard. The sitewide and all remaining property-specific scenarios are less than the target CR range. Consideration of CR above background results in only Plant 1 and DT-4 North being within the target CR range, with all remaining sitewide and property-specific scenarios being less than the target CR range and/or background.

Table K-16B presents potential health risks estimated for current/future utility workers associated with exposures to metal COPCs in a sitewide inaccessible soil scenario and eight property-specific inaccessible soil scenarios. The total CRs and HIs estimated for all sitewide and property-specific utility worker scenarios within the former uranium-ore processing boundary are less than the USEPA's target CR range and 1.0, respectively, as well as background.

In summary, total maximum radiological dose estimates above background for current/future utility worker exposures to inaccessible soil are all less than the target criteria of 25 mrem/yr. The maximum total radiological CRs above background estimated for utility worker exposures are within the USEPA's target range for Plant 1 and DT-4, with all remaining sitewide and property-specific scenarios being less than the target CR range and/or background. The total CRs and HIs estimated for all sitewide and property-specific utility worker scenarios within the former uranium-ore processing boundary are less than the USEPA's target CR range and 1.0, respectively, as well as background.

K2.5.4.6 Current/Future Industrial Worker Exposures to Radiological COPCs in Soil on Interior Surfaces of Buildings

Table K-17 presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for industrial worker exposures to radiological COPCs on interior surfaces of building. Radionuclide-specific COPCs were identified for interior surfaces for which gross alpha survey measurements were found to exceed the PRG of 130 dpm/100 cm^2. EPCs were determined from the gross alpha measurements and were subsequently converted to radionuclide-specific surface concentrations (pCi/m^2) through unit conversions and applications of SLDS-specific soil activity fractions. The resulting radionuclide-specific EPCs were then entered into the RESRAD-BUILD model to calculate total maximum doses and risks associated with interior radiation exposures to industrial workers who labor mainly indoors. Site-specific soil activity fractions used to generate radionuclide-specific EPCs are presented in Table K-3A, and interior building surface EPCs are presented in Table K-3B. As shown in Table K-3B, interior surface EPCs were determined for seven buildings located on four properties (Plant 1, Plant 2, DT-6, and DT-10).

The maximum total doses determined for all interior building surfaces are less than the target value of 25 mrem/yr. The maximum total CRs estimated for interior building surfaces are within USEPA's target CR range at five of the buildings evaluated: Plant 1 Building 7, Plant 1 Building 26, Plant 2 Building 41, Plant 2 Building 508, and DT-10 Metal Storage Building.

K2.5.4.7 Current/Future Maintenance Worker Exposures to Radiological COPCs in Soil on Exterior Surfaces of Buildings

Table K-18 presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for maintenance worker exposures to radiological COPCs on exterior surfaces of building/structures. Radionuclide-specific COPCs were identified for exterior surfaces for which gross alpha survey measurements were found to exceed the PRG of 3,200 dpm/100 cm^2. EPCs for exterior surfaces were determined using the same methodology used for interior surfaces, and then subsequently entered into the RESRAD-BUILD model to calculate total maximum doses and risks associated with maintenance workers who perform repair/maintenance or renovation work on building exteriors. As shown in Table K-3C, exterior surface EPCs were determined for three buildings located on two properties (Plant 1 and DT-10), and at DT-14 on a horizontal beam between the L-shaped building and brick warehouse.

The maximum total doses determined for all exterior surfaces are less than the target value of 25 mrem/yr. The maximum total CRs estimated for all exterior building surfaces are less than USEPA's target CR range, except for the DT-10 Wood Storage Building, the CR of which is within the target CR range.

K2.5.4.8 Current/Future Sewer Maintenance Worker Exposures to Radiological and Metal COPCs in Sewer Sediment

Table K-19A presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for current/future sewer maintenance worker exposures to sewer sediment. This receptor is evaluated for sitewide sewer sediment exposures to radiological COPCs, as well as for sewer sediment exposures to radiological COPCs at 26 individual manhole/surface drain locations within Plants 1, 2, 6, and 7 and near DT-11. All maximum total radiological doses and CRs estimated for this receptor are less than the target value of 25 mrem/yr and USEPA's target CR range, respectively.

Table K-19B presents health risks for current/future sewer maintenance workers associated with metal COPCs in sewer sediment inside of sewer lines. Arsenic is the only metal COPC identified for sewer sediment. This receptor is evaluated for sitewide sewer sediment exposures to arsenic, as well as for sewer sediment exposures to arsenic at 23 individual manhole/surface drain locations within Plants 1, 2, and 6 and DT-8. All total property CRs and HIs estimated for sewer maintenance worker exposures to arsenic in sediment are below the USEPA's target CR range and 1.0, respectively.

K2.5.4.9 Current/Future Utility Worker Exposures to Radiological and Metal COPCs in Soil Adjacent to Sewers

Table K-20A presents the maximum total radiological dose and CR results, estimated to occur over the 1,000-year evaluation period, for current/future utility worker exposures to radiological COPCs in soil adjacent to sewer lines at Plants 1, 2, and 6, Plant 7N/DT-12, DT-2, and DT-8 and DT-11. For radiological COPCs, this receptor is evaluated for sitewide exposures to soil adjacent to sewer lines and for radiological exposures at 41 individual soil borings locations and sewer line excavations.

Of the sitewide and 40 individual locations evaluated, the maximum total radiological doses estimated for the following five locations exceeded the target value of 25 mrem/yr:

- Location SLD93275 in Plant 7N/DT-12 (259 mrem/yr),
- Location SLD93276 in Plant 7N/DT-12 (75 mrem/yr),
- Location SLD93277 in Plant 7N/DT-12 (115 mrem/yr),
- Location SLD120945 in DT-2 (29 mrem/yr), and
- Location SLD120947 in DT-2 (30 mrem/yr).

The maximum total radiological CRs estimated for the following location exceeds the USEPA's target CR range:

- Location SLD93275 in Plant 7N/DT-12 (1.9E-04).

The maximum total radiological CRs estimated for the following locations are within the USEPA's target CR range:

- sitewide evaluation,
- Location HTZ88929 in Plant 6,
- Location HTZ88930 in Plant 6,
- Location SLD93276 in Plant 7N/DT-12,
- Location SLD93277 in Plant 7N/DT-12,
- Location SLD120945 in DT-2,
- Location SLD120946 in DT-2, and
- Location SLD120947 in DT-2.

When maximum total CRs above background are considered, the following location exceeds the USEPA's target CR range:

- Location SLD93275 in Plant 7N/DT-12 (1.9E-04).

The following locations are within the USEPA's target CR range when maximum total CRs above background are evaluated:

- sitewide evaluation,
- Location HTZ88929 in Plant 6,
- Location HTZ88930 in Plant 6,

- Location SLD93276 in Plant 7N/DT-12,
- Location SLD93277 in Plant 7N/DT-12,
- Location SLD120945 in DT-2,
- Location SLD120946 in DT-2, and
- Location SLD120947 in DT-2.

Potential health risks for current/future utility workers were estimated for exposures to the metal COPCs arsenic, cadmium, and lead in soil adjacent to sewer lines. Table K-20B presents the total CRs and HIs estimated for combined arsenic and cadmium exposures for the sitewide scenario, as well as for 27 location-specific scenarios. All total CRs and HIs are less than the USEPA's target CR range and 1.0, respectively.

Table K-20C presents potential health risks for pregnant utility workers exposed to lead in soil adjacent to sewer lines. Lead is classified as a B2 carcinogen, and it has known non-carcinogenic effects; however, no toxicity values have been established for lead. The USEPA regulates lead exposure using a biomarker (PbB), which can be estimated using the ALM.

As previously discussed in Section K2.4.2.5, the ALM is a biokinetic model that predicts the relative increase in PbB that might result from an environmental exposure. The ALM can be used to predict the risk of elevated PbBs in a non-residential setting as a result of adult exposures to soil, with the ultimate receptor being the fetus. The ALM assesses risk due to lead by predicting PbBs and comparing them to probability that a child will have a PbB greater than 10 µg/dL. This benchmark is used as the standard for evaluating risk from lead exposures.

Table K-20C presents the sitewide EPC for lead estimated across all samples collected from a total of 27 individual sampling locations. Additionally, the mean concentration of lead, calculated over all sampled depth intervals within each of the boring locations, is presented and used as the EPC for evaluating potential health risk to the utility worker at each boring location. Table K-20C also presents the predicted 95th percentile lead concentrations among fetuses of utility workers and the probability that fetal PbBs will exceed the established target of 10 µg/dL blood. Probabilities of less than 5 percent that fetal PbBs will exceed the established target of 10 µg/dL blood are considered to be protective. None of the 27 soil locations adjacent to sewers had a predicted probability that fetal PbBs would exceed the established target of less than 5 percent.

K2.6 UNCERTAINTIES ANALYSIS

There are a number of factors that contribute uncertainty to the estimates of dose and risk presented in Section K2.5. These uncertainties are inherent to each of the main components of the risk assessment process, as described in the following subsections for the industrial land use scenarios.

K2.6.1 Sampling and Dataset Uncertainties

To reduce uncertainties associated with characterizing SLDS ISOU media that could be impacted, either directly or indirectly, from past MED/AEC operations, a combination of biased and random sampling strategies were employed. The objective of media characterization was to develop a health-conservative risk assessment that would not underestimate actual risks to potentially exposed populations. The criteria used for determining locations of biased samples in ISOU media are presented in the RI WP (USACE 2009a).

Because of limited access to some ISOU media, contamination was characterized but not fully delineated in all cases. It is unknown whether media characterization over- or underestimated potential human health risks to likely ISOU receptors. Certainly, datasets of limited size that were generated around elevated measurement areas could have resulted in overestimations of risks due to relatively large standard deviations for the data set, elevating the 95 percent UCLs and, consequently, the EPCs. In some cases, the 95 percent UCLs were greater than the maximum detected concentration, and in these cases, the maximum detected concentration was used as the default EPC. Although a health-conservative risk assessment is desired in the CERCLA process, a lack of sample coverage results in uncertainty, because it does not adequately represent the probability of exposures as a receptor moves randomly about the evaluated area/building.

K2.6.2 Analytical Data Quality

Some unavoidable uncertainty is associated with the contaminant concentrations detected and reported by the analytical laboratory. The quality of the analytical data used in the risk assessment depends on the adequacy of the set of procedures that specifies how samples are selected and handled and how strictly these procedures are followed. QA/QC procedures within the laboratories are used to minimize uncertainties; however, sampling errors, laboratory analysis errors, and data analysis errors can occur.

Some current analytical methods are limited in their ability to achieve detection limits at or below risk-based PRGs. Under these circumstances, it is uncertain whether the true concentration is above or below the PRGs, which are protective of human health. Analytes identified as COPCs associated with datasets consisting of a mixture of detected and non-detected concentrations and risk calculations may be affected by the reported detection limits. Risks may be overestimated as a result of some sample concentrations being reported as non-detected at the maximum detected concentration or MDL, which may be greater than the PRG (when the actual concentration may be much smaller than the maximum detected concentration or MDL). Risks also may be underestimated, because some analytes that are not detected in any sample are removed from the COPC list. If the concentrations of these analytes are below the maximum detected concentration or MDL but are above the PRGs, then the risk from these analytes would not be included in the risk assessment results. However, for the ISOU, COPCs were selected based on exceedances of industrial risk-based PRGs. In most cases, industrial risk-based PRGs are sufficiently elevated so that they were not generally exceeded by detection limits. Screening COPCs using strictly risk-based PRGs introduces uncertainty when the PRG is below site-specific background values, as is the case for Ra-226, Ra-228, U-238, and arsenic. If one of these analytes were detected at a concentration above the PRG but below the background value, then risk from these analytes would be included in the risk assessment results even though it is present at below background concentrations. The aforementioned uncertainties regarding PRGs and detection limits did not result in significant uncertainties in COPC selection and subsequent risk evaluations.

K2.6.3 Selection of Contaminants of Potential Concern

The list of COPCs evaluated for the ISOU media is based on the list of radionuclides and metals associated with past MED/AEC operations and on those constituents that were identified as COCs in the 1998 ROD (USACE 1998a). During the 1993 BRA (DOE 1993), other constituents, including VOCs, PAHs, and other metals (antimony, beryllium, cobalt, copper, and nickel), were detected in the soil but either did not significantly contribute risk (e.g., VOCs) or did contribute risk but were not included on the COC list in the 1998 FS (USACE 1998b) and subsequent 1998

ROD, because they were determined to not be MED/AEC-related constituents (e.g., antimony, copper, nickel, and PAHs). For consistency with the June 1990 FFA, constituents not directly associated with former MED/AEC operations, or constituents that are not mixed or commingled in the investigated ISOU media with MED/AEC-related constituents, were not evaluated in this HHRA even if CRs or HIs were determined to be above the USEPA target criteria during the 1993 BRA. Although it is agreed that non-MED/AEC contaminants can contribute to the overall dose/risk for a receptor, the scope of the FUSRAP ISOU, is all media not covered by the 1998 ROD that may have become contaminated as a result of the deposition or migration of MED/AEC-related contaminated media. Therefore, RI data were collected to support characterization and delineation of the likely sources of MED/AEC-related contamination. For metals, the area of sampling and dose and risk characterization was the former uranium-ore processing area. The actual source(s) of metals in each soil sample collected cannot be reasonably discerned because of the wide-spread distribution and prevalence of metals throughout the uranium-ore processing area.

Besides having been associated with MED/AEC operations, COPCs were identified in ISOU media as those radiological and metal constituents detected at concentrations exceeding the PRGs presented in Table 4-1. For interior and exterior building surfaces, all gross alpha measurements were compared to PRGs of 130 dpm/100 cm^2 and 3,200 dpm/100 cm^2, respectively, which were derived based on interior industrial worker and exterior maintenance worker scenarios as part of this RI/BRA report (See Appendix S). A building surface was retained for further risk evaluation if a gross alpha result exceeded the corresponding surface PRG. The uncertainty analysis for the use of RESRAD-BUILD in the derivation of surface PRGs is presented in Appendix S, Section S3.0.

K2.6.4 Exposure Assessment

Quantification of exposure provides an estimate of the chemical intake for various exposure pathways identified at the site. For the ISOU HHRA, uncertainties associated with the various components of the exposure assessment include those related to representative EPCs and exposure parameters.

K2.6.4.1 Soil Exposure Areas and Exposure Point Concentrations

For the SLDS HHRA, inaccessible and accessible soil exposure areas were determined for each property/receptor scenario. Obtaining adequate sample coverage in inaccessible areas was largely a function of field conditions during sampling events. Inaccessible areas with low sample coverage introduced uncertainty. The lack of sample coverage in some inaccessible areas affects EPCs, dose and risk characterization of those areas, as well as property-wide dose and risk characterization. For example, most of the inaccessible soil data used for the Plant 6 HHRA exist at the southwestern corner and western boundary (i.e., Hall Street). Little sample coverage was achieved beneath existing buildings in the eastern portion of the Plant 6 property. Therefore, the EPC calculated for all inaccessible areas (collectively) at Plant 6 mainly reflects the western and southwestern portions of the property. Combining all inaccessible and accessible soil data into one dataset to calculate EPCs would result in giving equal weight across all accessible and inaccessible samples at a property. This in turn could potentially "dilute out" the impacts of elevated inaccessible areas, or hotspots, given that many of the accessible areas have been remediated. For this reason, area weighting was conducted for dose and risk rather than for EPCs, realizing the possibility exists that inaccessible soil might be over-represented in the combined inaccessible/accessible calculations for the property, which could result in an overestimation of actual dose and risk for Plant 6 and other properties.

When performing calculations of inaccessible and accessible soil area fractions for each property with and existing PRAR/FSSE, the size of the accessible area used is the area established by the combined survey unit areas presented in the PRAR/FSSE. Because some survey units cross property boundaries, and may include samples outside of the property boundary, the size of the combined accessible area for the property could be overestimated. Because the estimated size of inaccessible areas is calculated as the difference between the total property area and the PRAR accessible area, the inaccessible area could be slightly underestimated. The actual impacts to dose and risk estimation as a result of overestimated accessible area fractions, along with the inclusion of sample locations just outside of the property boundary, vary with each property and are dependent on other factors, such as sample coverage and the presence of hotspots. For properties without a PRAR/FSSE, accessible and inaccessible areas were both estimated. The overall inaccessible area for a property was estimated based on RI sample coverage, and the overall accessible area was generally calculated to be the difference between the total property area and the estimated inaccessible area. This could result in either an over- or underestimation of dose and risk results, and could be subject to change as additional future actions may be conducted at those properties. All uncertainties associated with property-wide evaluations will become minimized in the FS, as the focus narrows more to the evaluations of individual elevated measurement areas, including those areas beneath buildings that are driving overall property dose and risk.

Analytical results are used to calculate a mean concentration and the 95 percent UCL on the mean concentration. The lesser of the maximum detected concentration or the 95 percent UCL was used as the EPC for the HHRA. For the data sets containing a small number of samples with high sample variability resulting in high standard deviations, the maximum detected concentration was used as the EPC, representing a worst-case scenario. Therefore, doses and risks generated for elevated measurement areas are likely to have been overestimated.

Uncertainty that can be introduced by the data aggregation process was minimized by utilizing the USEPA's ProUCL program. ProUCL applied statistical tests to determine the distribution that best describes the dataset for each chemical within the area of concern. For each COPC, ProUCL reports the 95 percent UCL associated with the distribution type that best describes the dataset of interest. In many instances, 95 percent UCLs are calculated using both detected values and samples reported as non-detected. For data sets with non-detected results, ProUCL creates extrapolated values for non-detected results obtained using regression on order statistics. The EPC was determined to be the lesser of the maximum detected concentration versus the calculated 95 percent UCL. This method may moderately overestimate the EPC. In addition, when the resulting individual contaminant risks are summed to provide a total CR or HI, the compounding conservatism of this method for estimating EPCs likely has resulted in an overestimation of the total risk.

Additionally, it is conservatively assumed that chemical concentrations detected under current site conditions will remain constant for evaluations of future exposure scenarios. In other words, the measured concentrations (and resulting EPCs) are not reduced by loss due to natural removal processes such as volatilization, leaching, and/or biodegradation. This assumption is a source of uncertainty that tends to overestimate future exposure concentrations.

K2.6.4.2 Exposure Assumptions

For each exposure pathway chosen for analysis in the HHRA, assumptions are made concerning the exposure parameters (e.g., amount of contaminated media a receptor can be exposed to and intake rates for different routes of exposure) and the routes of exposure. The assumptions used are consistent with USEPA-approved default values, which are assumed to be representative of potentially exposed populations. However, in some cases, rather than apply default values, professional judgment was applied to allow for more realistic estimates. Examples of this are the exposure frequencies of 10 days for the duration of a small project involving utility work, and the assumption that a sewer maintenance worker will only work at each location one day per year.

For RESRAD evaluations, exposure parameters were selected to provide a conservative yet reasonable estimate of potential risks to each receptor. Site-specific measurements and data were used, as appropriate, to describe site conditions as accurately as possible. Where site-specific data were not available, standard default values were used or parameter values recommended by the USEPA's *Exposure Factors Handbook: 2011 Edition* (2011b) were chosen to provide reasonably conservative estimates of risk. For all scenarios, the RESRAD model assumes that contamination is always uniformly spread over the area assessed and is never covered in either the inaccessible or accessible soil areas. Assuming no cover over the contaminated zone, while applying the most reasonably maximum exposure scenario (i.e., the industrial worker), allows for a consistent assessment of dose and risk across all areas and provides a starting point for the dose and risk-based evaluations in the FS to support development of remedial alternatives.

Another area of uncertainty due to exposure assumptions is the application of direct contact exposure assumptions to inaccessible soils. This HHRA evaluates property-wide dose and risk for inaccessible soil, and for combined inaccessible and accessible soil at each property. For future exposure scenarios, the HHRA assumes that inaccessible soil has become accessible due to degradation or complete loss of ground cover. The types of ground cover that exist at the SLDS under current configurations includes, but may not be limited to, buildings, RRs, roadways, and pavement. Assuming direct contact with soils located beneath buildings or other permanent structures is highly conservative and tends to overestimate risk due to direct contact with inaccessible soils.

For the indoor and outdoor building occupancy scenario, actual areas of elevated activity were spotty, small, and non-removable compared to the uniform, partially removable contaminated area assumed in the model. Because the primary pathway for risk for the building occupancy scenario is inhalation, which is dependent on the level of removable contamination, assuming a higher-than-actual level of removable contamination results in overestimation of risk. Additionally, for these scenarios, gross alpha survey data were multiplied by SLDS COC activity fractions to get individual COC concentration values needed to estimate risk. This assumes that MED/AEC-related COC contamination on structures was at the same fraction of activity as that found in the soil. Because individual COC SFs vary, actual risk may vary depending on actual activity fractions.

The accuracy of exposure calculations is ultimately limited to the accuracy of the site data and RESRAD models. The data used in the assessment include results from several characterization efforts and include different target analytes, analysis methods, and reporting requirements. The data in this assessment are used assuming the best knowledge of the distribution of contaminants in site soil, with the goal of providing conservative yet reasonable estimates of risk. The models used to calculate risk and dose are approved by the USEPA and are designed to provide a reasonable prediction of site exposures that would not underestimate actual risks to potentially exposed populations.

K2.6.5 Toxicity Assessment

Uncertainties are inherent in the toxicity factors used to determine CRs for both radiological and metal COPCs, as well as for RfDs and RfCs used to determine HIs for metal COPCs.

K2.6.5.1 Toxicity Assessment for Radiological Contaminants of Potential Concern

In October 1999, Washington State University, under contract to the USACE, published a report titled *Determination of the In Vitro Dissolution Rates of Selected Radionuclides in Soil and Subsequent ICRP 30 Solubility Classification for Dosimetry* (WSU 1999). This report was used to support radiological dose and risk estimates for the HHRA. In vitro dissolution rates are broken into three classes: D, W, and Y (day, week, and year). Class D, W, and Y refer to retention time in the respiratory system and not necessarily retention time/exposure to the target organ. Sometimes the Class D or W is more limiting than the Class Y. Generally, RESRAD uses the most limiting dose conversion factor (whether it is Class D, W, or Y) for all COPCs.

Lifetime CR estimates are provided for exposure to chemical contaminants and are compared to the lower boundary of the CERCLA target risk range of 1.0E-06 to 1.0E-04. Although cancerous effects have only been detected at doses several orders of magnitude larger than those estimated at the SLDS, it is assumed that the SFs apply to both large and small radiological doses. Metal SFs are developed mostly from animal studies, and SFs for radionuclides and metal constituents incorporate several differences that may result in incompatibility. The USEPA, therefore, acknowledges a large (undefined) uncertainty in risk estimates and recommends that radiological and metal risks be presented separately (USEPA 1996b).

Radiological risk SFs have been developed primarily using data from groups such as the Japanese atomic bomb survivors. These individuals received large doses of radiation over a short period of time. By contrast, potential receptors in this assessment receive relatively small radiological doses over a long period of time. In addition, the calculations of SFs are based on radium dial painter studies, atomic bomb survivor studies, etc., each considering doses many orders of magnitude higher than those received at environmental levels.

A series of reports published by the National Research Council’s Committee on the Biological Effects of Ionizing Radiation lists additional uncertainties resulting from the use of CSFs for radionuclides. The National Research Council’s Committee on the Biological Effects of Ionizing Radiation report points out that CRs from exposure to radionuclides at ambient environmental levels (typical background radiation produces approximately 300 mrem/yr) are very difficult to distinguish from background cancer rates. The applicability of the linear no-threshold model has been debated by many professional societies. However, the linear no-threshold model (i.e., assuming risk is linear with exposure and is possible for even the smallest doses) has been adopted by all relevant U.S. regulating agencies. Using this model, risks at environmental levels are calculated even at dose levels a small fraction of background.

The determination of background at the SLDS may have been complicated by the presence of surficial fill consisting of brick, concrete, organic material, and coal slag with minor sand, coal ash, coal cinders, and silt that was used throughout the SLDS. A generalized stratigraphic column for the surficial fill present at SLDS is shown on Figure 3-1. BVs of some radionuclides and metals at the SLDS may be influenced by the presence of mixed fill materials.

K2.6.5.2 Toxicity Assessment for Metal Contaminants of Potential Concern

The methodology used to develop a non-carcinogenic toxicity value (RfD or RfC) involves identifying a threshold level below which adverse health effects are not expected to occur. The RfD and RfC values are based on studies of the most sensitive animal species tested (unless adequate human data are available) and the most sensitive endpoint measured. Uncertainties exist in the experimental dataset for such animal studies. These studies are used to derive the experimental exposure representing the highest dose level tested at which no NOAEL is demonstrated; however, only an LOAEL is available. The RfD and/or RfC is derived from the NOAEL (or LOAEL) for the critical toxic effect by dividing the NOAEL (or LOAEL) by uncertainty factors. These factors usually are in multipliers of 10, with each factor representing a specific area of uncertainty in the extrapolation of the data. For example, an uncertainty factor of 100 is typically used when extrapolating animal studies to humans. Additional uncertainty factors are sometimes necessary when other experimental data limitations are found. Because of the large uncertainties (10 to 10,000) associated with some RfD or RfC toxicity values, exact safe levels of exposure for humans are not known. For non-carcinogenic effects, the amount of human variability in physical characteristics is important in determining the risks that can be expected at low exposures and in determining the NOAEL (USEPA 1989a).

The toxicological data (SFs and RfDs) for dose-response relationships of metals are frequently updated and revised, which can lead to over- or underestimation of risks. These values are often extrapolations from animals to humans, and this can also cause uncertainties in toxicity values, because differences can exist in metal absorption, metabolism, excretion, and toxic response between animals and humans.

The USEPA considers differences in body weight, surface area, and pharmacokinetic relationships between animals and humans to minimize the potential to underestimate the dose-response relationship; as a result, more conservatism is usually incorporated into these steps. In particular, toxicity factors that have high uncertainties may change as new information is evaluated. Therefore, COPCs associated with high uncertainties in toxicity studies may be subject to regulatory change in the future. Finally, the toxicity of a contaminant may vary significantly with the metal form present in the exposure medium. For example, risks from metals may be overestimated, because they are conservatively assumed to be in their most toxic forms.

The carcinogenic potential of a metal can be estimated through a two-part evaluation involving: (1) a weight-of-evidence assessment to determine the likelihood that a metal is a human carcinogen, and (2) an SF assessment to determine the quantitative dose-response relationship. Uncertainties occur with both assessments. With respect to the likelihood that a chemical is a carcinogen, chemicals are categorized into 1 of 5 groups on the basis of weight-of-evidence studies of humans and laboratory animals (USEPA 2005): (1) Group A – known human carcinogen; (2) Group B – probable human carcinogen based on limited human data or sufficient evidence in animals, but inadequate or no evidence in humans; (3) Group C – possible human carcinogens; (4) Group D – not classified as to human carcinogenicity; and (5) Group E – evidence of no carcinogenic effects in humans.

The SF for a chemical is a plausible upper-bound estimate of the probability of a response per unit intake of a metal over a lifetime. It is used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. The SF is derived by applying a mathematical model to extrapolate from a relatively high, administered dose to animals to the lower exposure levels expected for humans. The SF represents the 95 percent UCL on the linear component of the slope (generally the low-dose region) of the tumorigenic dose-response curve. A number of low-dose extrapolation models have been developed, and the USEPA uses the linearized multi-stage model in the absence of adequate information to support other models. Therefore, methods used to derive SFs result in an overestimation of CRs in the HHRA.

Although the HHRA shows arsenic to be the only metal to exceed target risk levels, lead was also identified as a COPC in soil adjacent to sewers. Lead is classified as a B2 carcinogen, and it has known non-carcinogenic effects; however, no toxicity values have been established for lead. In comparison to most other environmental contaminants, the degree of uncertainty about the health effects of lead is quite low. Some of these effects, particularly changes in the levels of certain blood enzymes and in aspects of children's neurobehavioral development, may occur at PbBs so low as to be essentially without a threshold. For the SLDS, the ALM was used to associate environmental exposures with risk and inform cleanup decisions (relative to OSWER's risk reduction goal). The ALM was used to calculate both the probability that fetal PbBs would exceed the target level of 10 µg Pb/dL blood and to derive cleanup levels.

Based on recommendations of the Technical Review Workgroup for Lead, the ALM was run using updated ranges for the baseline PbB and GSD_i. However, recent scientific evidence has demonstrated adverse health effects at blood lead concentrations below 10 µg/dL down to 5 µg/dL, and possibly below. The USEPA is developing a new soil lead policy to address this new information. Uncertainty does exist regarding the adverse health effects for blood lead, however, until USEPA's new soil lead policy is finalized, the ALM run for the SLDS ISOU BRA is consistent with current guidance.

K2.6.6 Risk Characterization

Uncertainties inherent in risk characterization reflect the uncertainties inherent in all risk assessment elements leading up to the calculation of doses, CRs, and HIs. Uncertainties specific to the risk characterization of ISOU media are discussed below.

K2.6.6.1 Summation of Cancer Risks Across Radiological and Metal Contaminants of Potential Concern

Doses and CRs were estimated for both radiological and metal COPCs in inaccessible soil, accessible soil, sewer sediment, and soil adjacent to sewers. Gross alpha activity was evaluated for interior and exterior building surfaces. In areas where both radiological and metal CRs were estimated for inaccessible soil, the radiological and metal CRs are presented separately and were not summed together for the purpose of determining a total cumulative CR. The USEPA's RAGS, Volume I, Part A, (USEPA 1989a) cautions against combining radiological and chemical risks, because the derivations of SFs for radionuclides and metals are specific to distinct models incorporating different assumptions. USEPA outlines these differences in the *Radiation Exposure and Risk Assessment Manual* (USEPA 1996b). The major differences include the following.

- The radiological endpoint is fatal cancer – the endpoint for metals exposures is tumorigenic cancer or non-carcinogenic risk.
- Radiological risk estimates are based primarily on human data – metals risk estimates are based primarily on animal studies.
- Radiological risk estimates are based on the central estimate of the mean – metals risk estimates are based on 95 percent UCL of the mean.

Additionally, background radiation is ubiquitous at levels exceeding typical risk targets and natural variability may preclude the ability to quantify small incremental risks due to radiological contamination (USEPA 1996b). Therefore, risks calculated for radionuclides and metals were assessed separately and not summed together for the estimation of cumulative CRs.

K2.6.6.2 Summation of Non-Carcinogenic Hazard Indices

Uncertainties related to the summation of HQs and CRs across chemicals and pathways are generally a primary uncertainty in the risk characterization. In the absence of information on the toxicity of specific chemical mixtures, it is assumed that CRs and HQs are additive (i.e., cumulative) (USEPA 1989a). The limitations of this approach for non-carcinogens are: (1) the effects of a mixture of chemicals are generally unknown – it is possible that the interactions could be synergistic, antagonistic, or additive; (2) the RfDs have different accuracy and precision and are not based on the same severity or effect; and (3) HQ or intake summation is most properly applied to compounds that induce the same effects by the same mechanism. Therefore, the potential for occurrence of non-carcinogenic effects can be overestimated for chemicals that act by different mechanisms and on different target organs. In the HHRA, the metal COPCs exhibiting carcinogenic effects were arsenic and cadmium. Table K-10C shows that these metals affect different target organs and induce different systemic effects; therefore, summation results in an overestimation of the HIs calculated for each receptor.

K2.6.6.3 Risk Characterization of Lead Detected in Sewer Soil Boreholes

Lead concentrations were detected at several sewer soil locations at Plants 1, 2, 6, and Plant 7N/DT-12, as well as at DT-11, that exceed the 800-mg/kg industrial PRG. Although lead is classified as a B2 carcinogen and has known non-carcinogenic effects, no toxicity values have been established for lead. For the HHRA, the ALM was used to calculate both the probability that fetal PbBs would exceed the target level of 10 µg Pb/dL blood and to derive cleanup levels. This evaluation will be used to assess the need for further remediation during the FS. Results of the ALM model runs are presented in Appendix Q.

K2.6.6.4 Risk Characterization Including Background Levels

In the HHRA, SLDS background values are not subtracted from site concentrations or added to PRGs in order to reflect concentrations above SLDS background. Background is not subtracted from PRGs or concentration values used to develop EPCs prior to quantifying risk. Rather, background is used only for characterization purposes. Property dose and risk calculated without subtracting background may be grossly overestimated. This is a highly conservative assumption that tends to overestimate site risk.

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K3.0 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

The SLERA for the SLDS ISOU has been conducted documenting the process for evaluating the likelihood that the presence of radiological and metal PCOCs identified in ISOU media may adversely affect ecological receptors. The ISOU SLERA follows guidance provided in the USEPA's ERAGS (USEPA 1997b) and the USACE's *Environmental Quality – Risk Assessment Handbook, Volume II: Environmental Evaluation* (USACE 2010b). The entirety of the USEPA's SLERA process is comprised of the following eight steps:

- Step 1: Screening-Level Problem Formulation and Ecological Effects Evaluation
- Step 2: Screening-Level Preliminary Exposure Estimate and Risk Calculation
- Step 3: Baseline Risk Assessment Problem Formulation
- Step 4: Study Design and Data Quality Objectives
- Step 5: Field Verification of Sampling Design
- Step 6: Site Investigation and Analysis of Exposure and Effects
- Step 7: Risk Characterization
- Step 8: Risk Management.

In order to determine those steps that are most appropriate for the ISOU, the USACE reviewed the 1993 BRA, which evaluated potential receptor exposures to soil (mostly accessible), sediment, and surface water at the accessible soils OU. No field/laboratory investigations were conducted to determine the extent to which biota had been affected from past MED/AEC operations at the SLDS. The 1993 BRA primarily consisted of comparisons of contaminant concentrations reported for accessible environmental media with toxicity-based radiological and chemical threshold values available in literature. These comparisons were conducted in conjunction with in-depth toxicity assessments of radiological and chemical contaminants identified during the 1993 BRA and evaluations of other weights-of-evidence (e.g., actual contaminant fate and transport characteristics, exposure pathways, site characteristics, receptor characteristics, etc.) to assess if significant adverse ecological effects could be occurring at the SLDS.

The 1993 BRA concluded that the significance of contaminated media at the SLDS in regard to ecological resources is minimal due to the urban environment, limited wildlife habitat, and biotic diversity, and stated the following:

> *"…the significance of the St. Louis Site with regard to ecological resources is minimal, and intensive field analysis for possible impacts to biota from site contaminants is not warranted. Therefore, future efforts should emphasize concerns that related to human health effects, especially because radiological risks at the St. Louis Site are generally higher than chemical risks to humans by one order of magnitude"* (DOE 1993).

Therefore, all subsequent investigative and remediation activities conducted under the 1998 ROD focused on protection of human health. However, remedial actions being undertaken at the SLDS accessible OU are expected to be protective of both human health and the environment upon completion and to have reduced the likelihood that ISOU media will be impacted by accessible soil contamination.

Based on the results of the 1993 BRA, in conjunction with the results of a site visit to the ISOU in September 2010, only the completion of a portion of the Step 1 Problem Formulation was required for the ISOU in order to make one of three possible decisions at the end of the SLERA (USEPA 1997b): (1) there is adequate information to conclude that ecological risks are negligible, (2) the information is not adequate to make a decision, and the ecological risk assessment process moves to Step 3 (Baseline Ecological Risk Assessment), or (3) the information indicates a potential for adverse ecological effects, and more thorough assessment is warranted.

The following sections present the applicable portions of the Problem Formulation used to complete the ISOU SLERA.

K3.1 SLERA STEP 1 – SCREENING LEVEL PROBLEM FORMULATION

The first step of USEPA's approach to the SLERA process, Problem Formulation, includes:

- Environmental Setting and Contaminants at the Site,
- Contaminant Fate and Transport,
- Ecotoxicity and Potential Receptors, and
- Complete Exposure Pathways.

K3.1.1 Environmental Setting and Contaminants at the Site

K3.1.1.1 Environmental Setting

A site visit was conducted on September 10, 2010, to gather information necessary for completing the USEPA's Ecological Checklist (see Appendix R) regarding current environmental conditions at the ISOU relative to potential receptors. The SLDS is located in downtown St. Louis, Missouri, in an industrial land use area situated north of the city's center. The ground surface across the site is relatively flat, with a surface elevation of approximately 430 ft amsl in the southwestern part of the site to 420 ft amsl near the Mississippi River. Figure R-1 in Appendix R presents the topographic characteristics of the SLDS.

The SLDS has been continuously occupied since the 1800s and contains a number of industrial facilities. These facilities include the former Mallinckrodt facilities used in the production of nuclear fuel, a large metal recycling facility, a salt production facility, and several railway lines. The entire site, which encompasses approximately 210 acres of land, is highly disturbed, with areas containing several feet of fill material common throughout the site. A 500-year levee and floodwall separate the Mississippi River and the St. Louis Riverfront Trail from the industrial portions of the site.

The SLDS occupies the Oak-Hickory-Bluestem Parkland section of the Prairie Parkland Province. Pre-settlement vegetation is characterized by deciduous woodlands intermixed with open prairie. Today, the ecological resources at the SLDS are limited because of the site's location within an urban area of concentrated industrial and commercial developments (DOE 1993).

Of the 210 acres of total SLDS area, approximately 86 acres comprise the ISOU land area. There are no natural flowing or non-flowing water bodies at the ISOU with surface water or sediment. Any surface drainage from the ISOU (rain water, SLDS-generated, etc.) is directed by combined sanitary and sewer lines off-site to the MSD treatment plant (i.e., the Bissell Plant).

No wetlands occur within the ISOU, although according to the USFWS's National Wetlands Inventory (USFWS 2008), a portion of the SLDS area directly north of the McKinley Bridge and east of the Mississippi River levee is classified as palustrine wetlands (i.e., non-tidal wetlands that are substantially covered with emergent vegetation), which are commonly found along the Mississippi River. However, this area is not part of the ISOU, and based on the "Environmental

Assessment for Biota" presented in the 1993 BRA, no potentially sensitive habitats for biota occur either on or adjacent to the SLDS (DOE 1993).

There is limited ecological habitat at the ISOU. There are buildings, roads, sidewalks, and parking lots in active use, along with strips of disturbance-tolerant vegetation. Of the approximately 86 acres of ISOU land area, almost 6 acres contain vegetation. Therefore, the total ISOU land area covered by vegetation is approximately 7 percent of the ISOU land area and 3 percent of the SLDS land area. The limited vegetation, lack of suitable cover, and high level of disturbance is unattractive to wildlife. Only the hardiest urban receptors would use the site. No federal or Missouri threatened and endangered (T&E) species exist at the SLDS including the ISOU. Additional information addressing the overall environmental setting of the SLDS, including (1) topography, drainage, and surface water, (2) site geology and hydrogeology, and (3) ecological resources is presented in Sections 3.2, 3.3, and 3.4, respectively. The vegetation, wildlife, and habitats observed during the site visit are described in the Ecological Checklist (Appendix R).

K3.1.1.2 Contaminants in Inaccessible Soil and Soil on Buildings

As discussed in detail in Section 2.1, the inaccessible soil PCOCs selected in the RI WP as the starting point for the ISOU RI were those radionuclides and metals identified as COCs in the 1998 ROD (i.e., the primary radioactive contaminants in soil and sediment at the SLDS, including Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, and U-238, and the metal contaminants including arsenic, cadmium, and uranium metal) (USACE 1998a).

The derivation of chemical contaminants potentially attributable to MED/AEC operations indicated that chemical contamination consists primarily of elemental metal compounds resulting from uranium-ore processing operations in specific areas of the SLDS (USACE 1998b). The plant properties within the boundary where the uranium-ore processing was conducted by MED/AEC are Plant 2, Plant 6, and Plants 7N and 7S (Figure 1-2). Some VPs that are adjacent to these plant areas were also included in the MED/AEC uranium-ore processing area due to potential migration of contaminants. These VPs include DT-10, portions of DT-9 between Plants 2 and 6, portions of DT-12 adjacent to Plants 6 and 7, portions of Destrehan Street adjacent to Plant 2, Plant 6, Plants 7N and 7S, Hall Street between Plants 2 and 6, and portions of Mallinckrodt Street adjacent to Plant 2 (Figure 1-2). All other plant properties and VPs are outside of the uranium-ore processing area and, therefore, only have radiological PCOCs.

The same radiological PCOCs for soils are being evaluated for the building and structural surfaces. The 1993 BRA stated that chemical contaminants were not applicable to building surfaces; therefore, there are no metals PCOCs for building and structural surfaces (DOE 1993).

The list of PCOCs for the ISOU soil was defined as those radiological and chemical contaminants identified as being attributable to MED/AEC contamination, as shown in Table K-21.

K3.1.1.3 Contaminants in Sewer Sediment and Soil

The same radiological PCOCs for soils are being evaluated for sediment in sewers used for MED/AEC operations, as well as the soil adjacent to those sewers. Additionally, sewer sediment and soil adjacent to sewers used for MED/AEC operations were not analyzed for metals during past investigations; therefore, all metals associated with formerly used pitchblende and domestic ores were identified as PCOCs for sampling and analysis of sediment and soil adjacent to sewers

(See Table K-22). These metals include arsenic, cadmium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, thorium-metal, uranium-metal, vanadium, and zinc.

The list of PCOCs for the ISOU sewer sediment and soil adjacent to sewers was defined as those radiological and chemical contaminants identified as being attributable to MED/AEC contamination, as shown in Table K-22.

K3.1.2 Contaminant Fate and Transport

As discussed in Section 4.0, exceedances of human health PRGs were noted for inaccessible soil, sewer sediment, soil adjacent to sewers and building surfaces within the ISOU. However, the majority of the inaccessible soil is beneath ground cover present in the forms of buildings/structures, the levee, RRs, and roadways. As discussed in Section 5.0, the presence of the ground cover greatly reduces or mitigates surface release and transport mechanisms such as volatilization, fugitive dust, erosion, runoff, and leaching. Likewise, ground cover greatly reduces or mitigates subsurface release and transport mechanisms such as vertical leaching processes and horizontal migration in ground water because of the lack of infiltration from precipitation. There is currently no evidence of significant contaminant transport via ground water to more sensitive aquatic habitats offsite. However, further evaluation of potential risks to the environment from site ground water will be conducted as part of the Ground-Water Remedial Action Alternative Assessment initiated under the 1998 ROD. The information discussed previously concerning contaminant fate and transport was used in Section K3.1.2.2 to facilitate development of the CSM, which is presented schematically for both human health and ecological receptors in Figure K-3.

K3.1.2.1 Ecotoxicity and Potential Receptors

The next step of the Problem Formulation typically focuses on ecotoxicity and potential receptors. Knowing the toxic mechanism of a PCOC helps to determine the importance of potential exposure pathways and to focus the selection of assessment endpoints. However, because there are few complete exposure pathways, and those that are complete are insignificant at the ISOU (Section K3.1.2.2), there is limited usefulness in discussing the ecotoxicity of the PCOCs. Furthermore, no assessment and measurement endpoints have been selected based on the exposure pathway analysis. Instead, this section focuses solely on the potential receptors in order to provide useful supporting information for Section K3.1.2.2.

K3.1.2.1.1 Potential Receptors at the Inaccessible Soil Operable Unit

The SLDS is located within an industrial urban area with no potential for sensitive environmental areas and no natural ecological habitat. The Missouri Department of Conservation’s Natural Heritage database indicated that no T&E species are known to occur in the City of St. Louis. The only habitat present at the ISOU consists of small wooded areas and barren/field habitats. The wooded areas are located at three main areas (DT-2, DT-5, and DT-9) as shown in Figure R-2 of Appendix R. Open field areas are located along the levee (DT-9), at DT-1, and the Terminal RR Soil Spoils Area as shown in Figures R-2 and R-3 of Appendix R.

Vegetation

Site vegetation consists of a mixture of prairie species, disturbance-related aggressive species, and species typical of old fields. The largest vegetated area on the site is the area adjacent to the Mississippi River along the levee. This area is maintained as mowed turf grass. A highly disturbed, linear forested area is located immediately adjacent to the Mississippi River. This approximately 4.5-acre fragmented woodland, which includes a portion of the ISOU, is dominated by disturbance-tolerant species such as mulberry (*Morus* sp.), eastern cottonwood (*Populus deltoides*), Amur honeysuckle (*Lonicera maackii*), and Japanese honeysuckle (*Lonicera japonica*). A few American sycamore (*Platanus occidentalis*) and silver maple (*Acer saccharinum*) trees are also present. There is almost no understory present in the woodland.

Other large, vegetated areas at the SLDS that are not part of the ISOU land area include a small wooded area adjacent to the Terminal RR tracks, a wooded area adjacent to the Ameren UE electrical station (DT-5), and a former building site (DT-1). All of these areas are characterized by disturbance-tolerant species such as tree of heaven (*Ailanthus altissma*), Amur honeysuckle, Johnson grass (*Sorghum halepense*), and ragweed (*Ambrosia artemisiifolia, A. trifida*). These areas are described in more detail in Sections IIIA1 and IIIA3 of Appendix R.

Other vegetation observed at the site include black locust, as well as annual and perennial weed species, such as common sunflowers, spotted spurge, and foxtail. The 1993 BRA noted the presence of wild carrot, aster, clover, dandelion, milkweed, ragweed, and various grasses.

Terrestrial Receptors

Few terrestrial receptors are likely to inhabit the site, because the patchiness of the vegetation, lack of vegetative cover and water, and high level of disturbance are unattractive to wildlife. The only receptors likely to use the site would be urban-adapted species. Wildlife observations during the September 2010 site visit included several bird species (swallow, sparrow, robin, cardinal, mourning dove, and mockingbird), an eastern cottontail rabbit, as well as a groundhog den, raccoon tracks, and beaver cuttings.

The 1993 BRA noted that vertebrate fauna of the St. Louis area consist of species that have adapted to urban encroachment, including mammals (e.g., mice, opossum, eastern cottontail rabbit, gray squirrel, and eastern mole). Birds that inhabit the urban environment include the Canada goose, rock dove, mourning dove, American crow, American robin, and Northern cardinal (DOE 1993).

Aquatic Receptors

The only flowing or non-flowing water systems that exist at the SLDS are associated with surface runoff following precipitation events and the subsurface sewer system. All flow from surface runoff is captured by the sewer system and is subsequently directed to a local treatment facility. There are no open and natural flowing or non-flowing water systems at the SLDS capable of sustaining sensitive aquatic species, and no aquatic species or habitats were observed at the SLDS throughout the RI and the September 2010 site visit. There are no off-site surface water discharges from the ISOU to the Mississippi River that could directly impact riparian or aquatic species. In summary, based on these observations and the findings presented in the 1993 BRA, there is currently no evidence of sensitive on-site or off-site aquatic receptors with the potential for being adversely exposed to contaminants identified in ISOU media.

K3.1.2.2 Complete Exposure Pathways

The CSM for human health and ecological receptors, as presented in Figure K-3, indicates that exposure pathways are either incomplete, or are complete but insignificant for aquatic and terrestrial receptors. Site concentrations were not compared to ecological screening levels, because there are no complete and significant exposure pathways, as explained in the following items.

- There are no streams, ponds, or surface water bodies at the SLDS, and the potential for off-site contaminant migration via surface water is low due to run-off collection in sewers.

- There are no significant migration pathways for sediment in sewer lines, except through possible leaks or breaks in the lines, which could result in impact to adjacent and underlying soil. However, this soil is largely inaccessible to ecological receptors and not expected to result in adverse effects.
- Ground water at the SLDS is encountered around 7 to 32 ft bgs depending on the location within the site. Even burrowing mammals are unlikely to be exposed to environmental media this far below the ground surface. Ecological receptors are, therefore, not directly exposed to ground water at the SLDS. There is currently no evidence of significant contaminant transport via ground water to more sensitive aquatic habitats off site. However, further evaluation of potential risks to the environment from site ground water will be conducted as part of the Ground-Water Remedial Action Alternative Assessment initiated under the 1998 ROD.
- Radiological contamination on exterior building surfaces has been determined to be fixed, with very limited potential for removal via natural weathering processes; therefore, there is no likelihood for impacts to ecological receptors.
- The largest vegetated area at the ISOU is the area adjacent to the Mississippi River along the levee. The uptake of site contaminants by trees along the levee is limited, because this area is maintained so that large trees do not grow and potentially affect the structural integrity of the levee. The majority of this area is maintained as mowed turf grass. As a result, the number of trees that could potentially be exposed to contaminants through root uptake would be limited.
- While burrowing animals could be exposed to contaminants via ingestion and inhalation of soil if they burrowed into the inaccessible soils area, these exposures are expected to be insignificant due to the limited number of such animals expected to occur in the ISOU areas. Worms and insects would have limited exposure to the inaccessible soils, which are typically beneath ground cover (e.g., buildings, asphalt). With limited exposure to prey items that had been exposed to inaccessible soils, birds would not be at risk from consuming these invertebrates.

Given the information discussed previously, and based on the results noted in the Ecological Checklist in Appendix R, it is concluded that there are no complete or significant exposure pathways for ecological receptors at the ISOU. This is primarily because the majority of the site is covered by sidewalks, roads, buildings, and parking lots, which inhibit contaminant mobility, especially in the subsurface. In addition, most of the samples collected from ISOU media were collected from areas of the site not readily accessible to wildlife, limiting direct contact between contaminants and ecological receptors.

Based on the findings of the Ecological Checklist (Appendix R), as well as the results of the 1993 BRA ("Environmental Assessment for Biota"), no potentially important habitats for biota occur either on site or adjacent to the SLDS (DOE 1993). Lastly, there are no sensitive or unique ecological receptors located within the site.

K3.1.3 Summary and Recommendations

The 1993 ecological evaluation determined that potential impacts to ecological receptors from accessible environmental media at the SLDS are likely to be insignificant, because the SLDS is a heavily urbanized area not suitable for habitation of sensitive and T&E species. In comparison to the accessible media evaluated in the 1993 BRA, the potential for impacts to ecological receptors from ISOU media evaluated in this SLERA is significantly less for the following reasons. First, based on the lack of suitable habitat, the potential for direct contact exposures to ISOU media is reduced for terrestrial or aquatic ecological receptors. Second, the presence of buildings and consolidated cover (e.g. asphalt and concrete pavement) over inaccessible soil acts as a physical barrier to direct contact exposures by terrestrial receptors. Third, the potential for subsurface migration to sensitive terrestrial or aquatic habitats (although none have been found to exist, per the Ecological Checklist in Appendix R,) from inaccessible soil is not significant. Thus, it is concluded that there are no complete or significant exposure pathways for ecological receptors at the ISOU. Finally, remedial actions conducted at the SLDS under the 1998 ROD have reduced the likelihood that ISOU media will be impacted by accessible soil contamination. It is for the aforementioned reasons that contaminant screening was not conducted in the ISOU SLERA and no further action was recommended from an ecological perspective.

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K4.0 SUMMARY OF THE BASELINE RISK ASSESSMENT

A BRA was performed to estimate current and potential future dose and risks to human and ecological receptors that could result from exposures to radiological and metals COPCs in inaccessible soil and sewer sediment that were not addressed in the 1998 ROD (USACE 1998a). The BRA consists primarily of two components: a quantitative HHRA and a SLERA, the summaries and findings of which are discussed in the following subsections.

K4.1 HUMAN HEALTH RISK ASSESSMENT

A comprehensive HHRA was completed based on the identification of radiological and metal COPCs in Section 4.0. The purpose of the HHRA is to provide risk and dose estimates and HI values for ISOU media and properties. The following nine receptor scenarios and the associated data sets were evaluated:

- current industrial worker exposures to inaccessible soil and combined inaccessible/ accessible soil,
- future industrial worker exposures to inaccessible soil and combined inaccessible/ accessible soil,
- current/future recreational user exposures to inaccessible soil and combined inaccessible/ accessible soil in the levee areas associated with the St. Louis Riverfront Trail,
- current/future construction worker exposures to inaccessible soil,
- current/future utility worker exposures to inaccessible soil,
- current/future industrial worker exposures to interior building surfaces,
- current/future maintenance worker exposures to exterior building surfaces,
- current/future sewer maintenance worker exposures to sediment inside of sewer lines, and
- current/future sewer utility worker exposures to soil adjacent to sewer lines.

The previously listed scenarios assume (1) current land use configurations in which ground cover is present over most inaccessible soil areas, but is absent from accessible soil areas, and (2) future land use configurations in which ground cover is absent from both inaccessible and accessible soil areas. In other words, for future exposure scenarios, the HHRA assumes that inaccessible soil has become accessible due to degradation or complete loss of ground cover. Each of the previous scenarios, except for building surfaces, were evaluated for sitewide dose and risk. Additionally, property-specific evaluations were conducted for inaccessible soil and combined inaccessible/accessible soil; building-specific evaluations were evaluated for soil on interior and exterior building surfaces; and sampling location-specific dose and risk evaluations were conducted for sewer sediment and soil adjacent to sewer lines.

A hypothetical resident gardener scenario was evaluated but is presented separately, in Attachments K-1 and K-2 to this appendix. This is because current land use is predominantly industrial/commercial, and land use is expected to remain as such for the foreseeable future; therefore, it is recommended that scenarios assuming industrial land use be used as the basis for determining future actions at the ISOU. The hypothetical resident gardener was evaluated as an unlimited use and unrestricted exposure scenario for only informational purposes to facilitate future decision making as needed. As discussed in Attachment K-1, weight-of-evidence considerations generally suggest that doses and risks estimated for a resident gardener scenario represent overestimations of actual doses and risks associated with inaccessible soil.

The maximum total radiological doses and risks for all sitewide and property-/location-specific receptor scenarios, including the corresponding maximum total background dose and risk, that occur over the 1,000-year evaluation period, are presented in Tables K-2, K-3A, K-4, K-5A, K-6A, K-7, K-8, K-9A, and K-10A. These tables show dose above background (i.e., background dose is subtracted from the site dose), as well as CRs both with and without background. Radiological doses and CRs estimated for background are presented in Table K-11A, as well as in the aforementioned dose and CR summary tables. Doses and CRs are presented above background for consistency with the work being conducted under the 1998 SLDS ROD at the same properties being evaluated for ISOU-related doses and CRs.

The CRs and HIs estimated for metals for all sitewide and property-/location-specific receptor scenarios, including the corresponding background CRs and HIs, are presented in Tables K-3B, K-5B, K-6B, K-9B, K-10B, and K-10C. Unlike the radiological dose and risk characterization tables, only CRs and HIs inclusive of background are being presented for metals for consistency with CERCLA methodology, which are then qualitatively compared to background CRs and HIs estimated for the corresponding receptor scenarios. Background CRs and HIs for metals are presented in Table K-11B, as well as in the aforementioned site CR and HI summary tables.

For the sitewide evaluations in the HHRA, receptor exposures to radiological and/or metal COPCs in the following media result in CRs above background that are within or exceed the USEPA's target CR range: inaccessible soil, combined inaccessible/accessible soil, and soil adjacent to sewer lines. Additionally, the HHRA results indicate that Plant 1 and DT-4 North exhibit radiological doses above background that exceed the target value of 25 mrem/yr. Of the 28 individual properties evaluated for radiological and metal exposures to inaccessible soil and/or combined inaccessible and accessible soil, 23 properties exhibit CRs above background that are within or exceed the USEPA's target CR range. The HHRA also shows that five buildings present at 3 properties (Plant 1, Plant 2, and DT-10) exhibit CRs for interior surfaces that are within the USEPA's target CR range. Only one building at DT-10 exhibits a CR for exterior surfaces within the USEPA's target CR range. None of the building surfaces exceed the target dose value. The sitewide evaluation of soil adjacent to sewers and the evaluations of eight individual soil locations adjacent to sewers resulted in exceedances of the target dose and/or resulted in the CRs being within or in exceedance of the target CR range for radiological exposures. All of the metal evaluations of soil adjacent to sewers resulted in all CRs and HIs being less than the target CR range and 1.0, respectively. All of the ALM evaluations of soil adjacent to sewers resulted in health risk due to lead being less than the USEPA's benchmark criterion. Of the metal COPCs evaluated in inaccessible soil (arsenic) and soil adjacent to sewers (arsenic, cadmium, and lead), ingestion of arsenic was the predominant contributor to risk. None of the sewer sediment locations exceed target dose or risk criteria.

K4.2 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT

A SLERA was conducted for the ISOU that followed the USEPA's approach for the first step of the SLERA process, Problem Formulation, which included:

- Environmental Setting and Contaminants at the Site,
- Contaminant Fate and Transport,
- Ecotoxicity and Potential Receptors, and
- Complete Exposure Pathways.

The findings of a September 10, 2010, site visit were used as the basis in completing the SLERA. These findings are documented in the USEPA's Ecological Checklist, which includes detailed information regarding the environmental setting, potential receptors, contaminant fate and transport, and exposure pathways per USEPA guidance (USEPA 1997b). Based on these findings, there are no complete or significant exposure pathways for ecological receptors at the ISOU. In addition, remedial actions conducted at the SLDS under the 1998 ROD have reduced the likelihood that ISOU media will be impacted by accessible soil contamination. As a result, no further action was recommended from an ecological perspective.

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FIGURES

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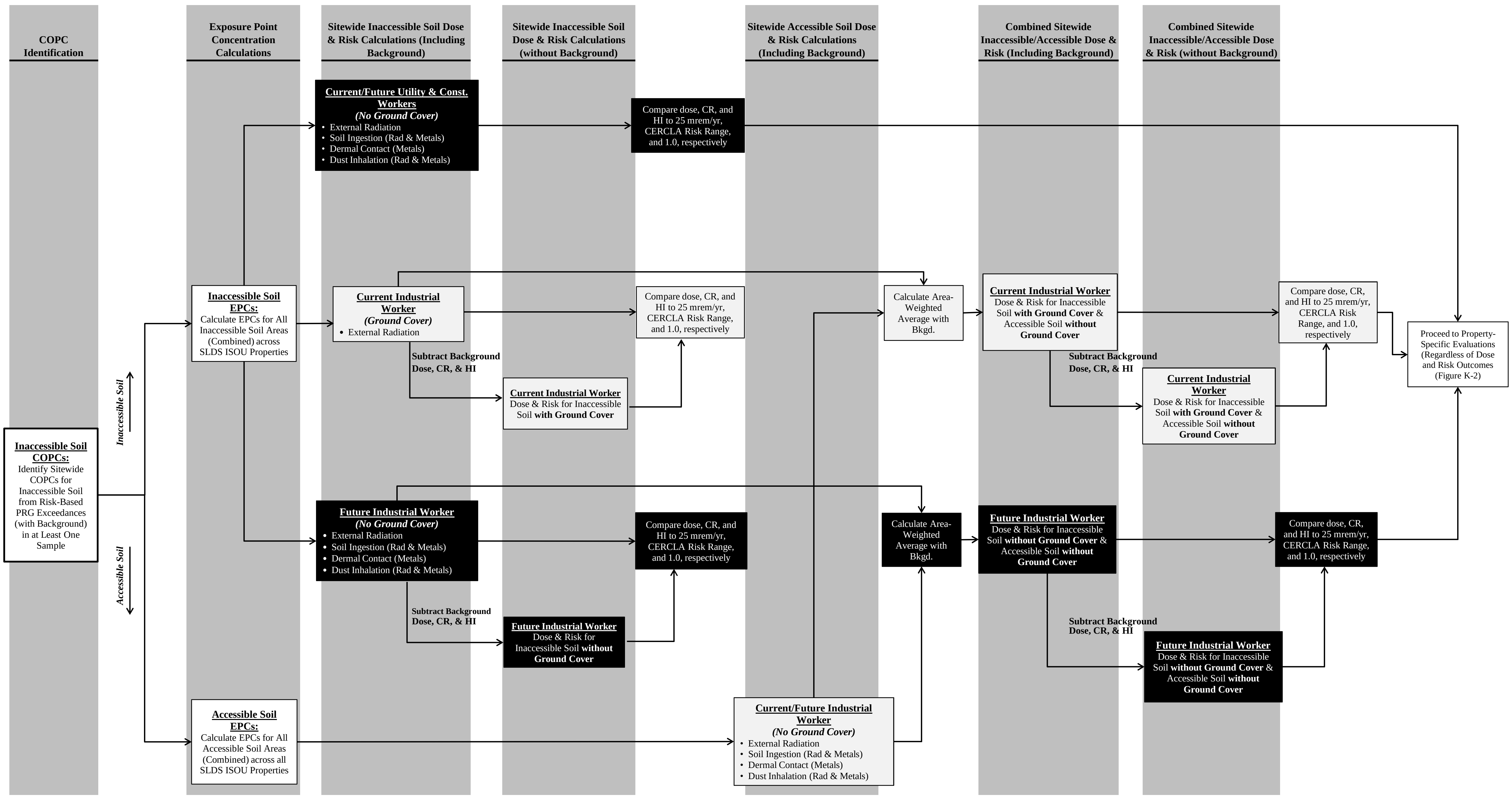


RECEPTOR SCENARIOS:

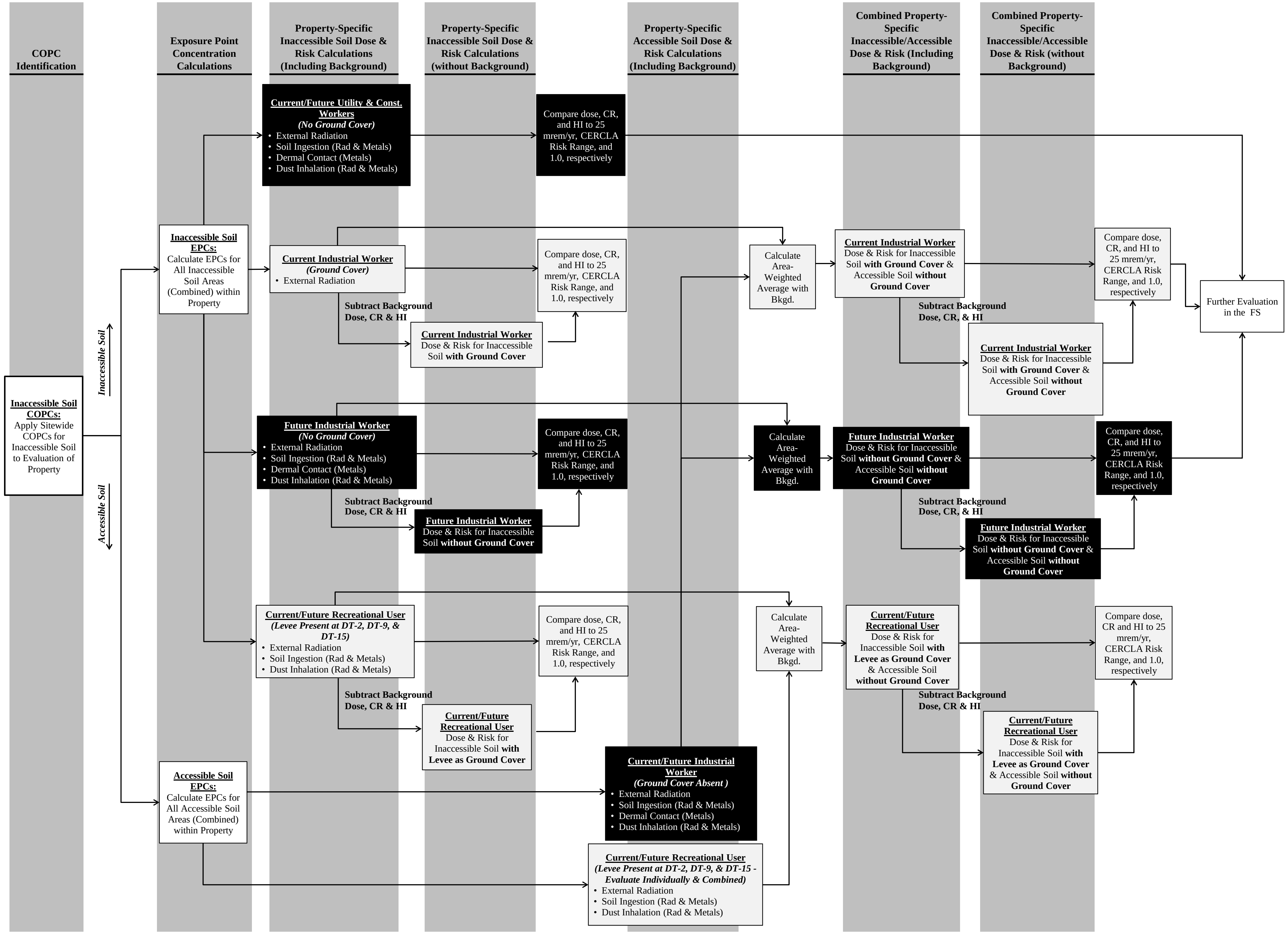
Current/Future Utility & Construction Worker - Inaccessible soil evaluations with no ground cover assumed to be present over excavated

Current Industrial Worker - Inaccessible soil and combined inaccessible/accessible soil evaluations, with ground cover assumed to be present over inaccessible soil areas.

Future Industrial Worker - Inaccessible soil and combined inaccessible/accessible soil evaluations, with no ground cover assumed to be present over inaccessible soil

Current/Future Industrial Worker - Accessible soil evaluations, with no ground cover assumed to be present.

Figure K-1. Sitewide ISOU Human Health Risk Assessment Process for Soil



RECEPTOR SCENARIOS:

Current/Future Utility & Construction Worker - Inaccessible soil evaluations with no ground cover assumed to be present over excavated inaccessible soil.

Current Industrial Worker - Inaccessible soil and combined inaccessible/accessible soil evaluations, with ground cover assumed to be present over inaccessible soil areas.

Future Industrial Worker - Inaccessible soil and combined inaccessible/accessible soil evaluations, with no ground cover assumed to be present over inaccessible soil areas.

Current/Future Recreational User of St. Louis Riverfront Trail - Inaccessible soil and combined inaccessible/accessible soil evaluations. Levee assumed to be always present as ground cover over inaccessible soils at DT-2, DT-9, and DT-15.

Current/Future Industrial Worker - Accessible soil evaluations, with no ground cover assumed to be present.

Current/Future Recreational User of the St. Louis Riverfront Trail - Accessible soil evaluations for DT-2, DT-9, and DT-15. No ground cover assumed.

Figure K-2. SLDS ISOU Property-Specific Human Health Risk Assessment Process for Soil

Source	Release/ Transport Mechanism	Exposure Medium/ Secondary Source	Release/ Transport Mechanism	Exposure Medium	Exposure Routes	Potential Human Receptors: Current Industrial Worker	Future Industrial Worker	Current/Future Construction Worker	Current/Future Utility Worker	Current/Future Sewer Maintenance Worker	Current/Future Recreational User (St. Louis Riding Trail)	Future Resident	Ecological Receptors[a]: Aquatic	Terrestrial
Inaccessible Soil Beneath Ground Cover[b]					External Radiation	2					2			1
					Ingestion (Rad & Metals)									1
					Dermal Contact (Metals)									1
	Particulate Emissions	Air			Dust Inhalation (Rad & Metals)									1
	Rn-222 Emissions	Air			Rn-222 Inhalation[h]	1	1	1	1	1				1
	Infiltration/ Percolation	Ground Water[c]			External Radiation									
					Ingestion (Rad & Metals)									
					Dermal Contact (Metals)									
	Surface Runoff	Surface Water/ Sediment in Mississippi River			External Radiation								1	1
					Ingestion (Rad & Metals)								1	1
					Dermal Contact (Metals)								1	1
Inaccessible Soil with No Ground Cover[d]					External Radiation		2	2	2					1
					Ingestion (Rad & Metals)		2	2	2					1
					Dermal Contact (Metals)		2	2	2					1
	Particulate Emissions	Air			Dust Inhalation (Metals & Rad)		2	2	2					1
	Rn-222 Emissions	Air			Rn-222 Inhalation[h]	1	1	1	1	1				1
	Infiltration/ Percolation	Ground Water[c]			External Radiation			1	1					
					Ingestion (Rad & Metals)			1	1					
					Dermal Contact (Metals)			1	1					
	Surface Runoff	Surface Water/ Sediment in Mississippi River			External Radiation								1	1
					Ingestion								1	1
					Dermal Contact (Metals)								1	1
Soil on Structural Surfaces[e]					External Radiation	2	2	1						
					Ingestion (Rad)	2	2	1						
	Dust Emissions From Renovation/ Construction; Oxidized Particulates from Metal Surfaces	Air			Dust Inhalation (Rad)	2	2	1						
	Surface Runoff	Surface Water/ Sediment/Biota in Mississippi River			External Radiation								1	1
					Ingestion (Rad)								1	1
Sewers (Sediment)[f]					External Radiation				1	2				
					Ingestion (Rad & Metals)				1	2				
					Dermal Contact (Metals)				1	2				
	Particulate Emissions	Air			Dust Inhalation (Rad & Metals)				1	1				
	Leakage from Sewer Line	Inaccessible Soil Adjacent to Sewer Lines[g]			External Radiation				2	1				
					Ingestion (Rad & Metals)				2	1				
					Dermal Contact (Metals)				2	1				
			Particulate Emissions	Air	Dust Inhalation (Rad & Metals)				2	1				
			Infiltration/ Percolation	Ground Water[c]	External Radiation				1	1				
					Ingestion (Rad & Metals)				1	1				
					Dermal Contact (Metals)				1	1				
				Surface Water/ Sediment in Mississippi River	External Radiation									
					Ingestion (Rad & Metals)									
					Dermal Contact (Metals)									

Notes

KEY:

(shaded) Incomplete exposure pathway. Pathway is not evaluated in the BRA.

1 Pathway is potentially complete, but is considered unlikely, insignificant, or out of scope for the ISOU. Pathway is not quantitatively evaluated in the BRA. For Rn-222, the pathway is currently indeterminate due to insufficient data.

2 Potentially complete and significant exposure pathway. Pathway is evaluated in the BRA.

NOTES:

[a] Ecological receptors include animals and plants.

[b] SLDS-wide and property-specific inaccessible soil beneath ground cover is being evaluated under the current industrial land use scenario.

[c] There are no complete or significant human or ecological exposure pathways for ground water.

[d] SLDS-wide and property-specific inaccessible soil with no ground cover is being evaluated under the future industrial worker scenario, as well as for current/future construction and utility worker scenarios.

[e] Includes interior and exterior surfaces containing radiologically contaminated soil. Industrial worker exposures are assumed for interior surfaces, and exposures to industrial workers performing maintenance are assumed for exterior surfaces and roofs. Industrial workers are assumed to be exposed 2,000 hours per year for 25 years. Industrial maintenance workers are assumed to be exposed 80 hours per year for 1 year.

[f] Sewers are considered to be a source, and the first medium assumed to have been impacted by MED/AEC operations is sediment inside of sewer lines. Sewer sediment exposures are assumed to occur infrequently during internal sewer line maintenance activities. Dust inhalation is not evaluated, because the moisture content of the sediment is assumed to preclude dust emissions. Soil adjacent to sewers are also part of this source.

[g] Because radiological and metals contamination in soil adjacent to sewer lines is likely due to sewer line leaks, soil adjacent to sewer lines is considered to be a secondary source. Pathways are considerd complete and significant due to recent sewer removal/replacement work that has been conducted.

[h] Only Rn-222 emissions from inaccessible soil to indoor air are considered for occupied or habitable buildings. Rn-222 emissions from inaccessible soil to outdoor air are not considered significant, as explained in Section 5.2.1.2.

Figure K-3. Human Health and Ecological Conceptual Site Model for St. Louis Downtown Site, Inaccessible Soil Operable Unit

TABLES

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Table K-1. Property and Medium-Specific Receptor Scenarios for Evaluation in the Human Health Risk Assessment

Property	Inaccessible Soil [a] (Ground Cover Present)		Inaccessible Soil [a] (Ground Cover Absent)			Combined Inaccessible and Accessible Soil [a] (Ground Cover Absent in Accessible Areas)			Building/ Structural Surfaces [b, c]		Sewers [d]	
	Current Industrial Worker [e]	Current/ Future Recreational User [f]	Future Industrial Worker	Current/ Future Construction Worker	Current/ Future Utility Worker	Current Industrial Worker (Ground Cover Present in Inaccessible Areas) [e]	Future Industrial Worker (Ground Cover Absent from Inaccessible Areas)	Current/Future Recreational User (Levee Present as Ground Cover)	Current/ Future Industrial Worker (Interior Surfaces)	Current/ Future Maintenance Worker (Exterior Surfaces)	Current/ Future Utility Worker (Soil Adjacent to Sewers)	Current/ Future Sewer Maintenance Worker (Sediment)
Sitewide Scenarios												
Background [f]	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	Radiological	Radiological
SLDS (Sitewide) [g]	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological + As	---	---	---	Radiological + As, Cd, Pb	Radiological + As
Combined Properties with St. Louis Riverfront Trail [h]	---	Radiological	---	---	---	---	---	Radiological	---	---	---	---
Property-Specific Scenarios												
Plant 1	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	Radiological	Radiological	Radiological + As, Cd, Pb	Radiological + As
Plant 2	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological + As	---	Radiological	---	Radiological + As, Cd, Pb	Radiological + As
Plant 3	---	---	---	---	---	---	---	---	---	---	---	---
Plant 6	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological + As	---	---	---	Radiological + As, Cd, Pb	Radiological + As
Plant 7N/DT-12	---	---	---	---	---			---	---	---	Radiological + As, Cd, Pb	Radiological + As
Mallinckrodt Security Gate 49	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-2	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	Radiological	---
DT-4 North [i]	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-6 [i]	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	Radiological	---	---	---
DT-8	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-10	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological + As	---	Radiological	Radiological	---	---
DT-11 and DT-8	---	---	---	---	---	---	---	---	---	---	Radiological + As, Cd, Pb	Radiological + As
DT-14	---	---	---	---	---	---	---	---	---	Radiological	---	---
DT-15	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---
DT-29	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-34	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
West of Broadway Property Group [j]	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
South of Angelrodt Property Group [k]	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-3	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-9 Rail Yard	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-9 Main Tracks	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological + As	---	---	---	---	---
DT-9 Levee	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---
Terminal RR Association Soil Spoils Area	Radiological	---	Radiological	Radiological	Radiological	Radiological	Radiological	---	---	---	---	---
DT-12	Radiological	---	Radiological + As	Radiological + As	Radiological + As	Radiological	Radiological	---	---	---	---	---
Hall Street	Radiological	---	Radiological + As	Radiological + As	Radiological + As	---	---	---	---	---	---	---
North Second Street	Radiological	---	Radiological	Radiological	Radiological	---	---	---	---	---	---	---
Bremen Avenue	Radiological	---	Radiological	Radiological	Radiological	---	---	---	---	---	---	---
Salisbury Street	Radiological	---	Radiological	Radiological	Radiological	---	---	---	---	---	---	---

Table K-1. Property and Medium-Specific Receptor Scenarios for Evaluation in the Human Health Risk Assessment

Property	Inaccessible Soil [a] (Ground Cover Present)		Inaccessible Soil [a] (Ground Cover Absent)			Combined Inaccessible and Accessible Soil [a] (Ground Cover Absent in Accessible Areas)			Building/ Structural Surfaces [b, c]		Sewers [d]	
	Current Industrial Worker [e]	Current/ Future Recreational User [f]	Future Industrial Worker	Current/ Future Construction Worker	Current/ Future Utility Worker	Current Industrial Worker (Ground Cover Present in Inaccessible Areas) [e]	Future Industrial Worker (Ground Cover Absent from Inaccessible Areas)	Current/Future Recreational User (Levee Present as Ground Cover)	Current/ Future Industrial Worker (Interior Surfaces)	Current/ Future Maintenance Worker (Exterior Surfaces)	Current/ Future Utility Worker (Soil Adjacent to Sewers)	Current/ Future Sewer Maintenance Worker (Sediment)
Mallinckrodt Street	Radiological	---	Radiological + As	Radiological + As	Radiological + As	---	---	---	---	---	---	---
Destrehan Street	Radiological	---	Radiological + As	Radiological + As	Radiological + As	---	---	---	---	---	---	---
Angelrodt Street	Radiological	---	Radiological	Radiological	Radiological	---	---	---	---	---	---	---
Buchanan Street	Radiological	---	Radiological	Radiological	Radiological	---	---	---	---	---	---	---

[a] Radiological COPCs for inaccessible soil were identified by exceedances of corresponding PRGs by at least one sample result throughout SLDS. Radiological COPCs always include the following: Ac-227, Pa-231, Ra-226, Ra-228, Th-230, Th-232, U-235, and U-238. Th-228 is not a COPC due to no exceedances of the PRG. Metals were only identified as COPCs if they exceed the PRG within the uranium ore processing area (see Figure 1-2) by at least one sample result. For the combined inaccessible and accesssible soil evaluations, the COPCs are the COCs identified in the 1998 ROD.

[b] Radiological COCs that were identified in the 1998 ROD are retained as the COPCs for soil on structural surfaces, because it is assumed that the soil on structural surfaces originated from accessible areas. These include the following: Ac-227, Pa-231, Ra-226, Ra-228, Th-228, Th-230, Th-232, U-235, and U-238. There are no metal COPCs for structural surfaces.

[c] The following identifies buildings at each property for which structural surfaces are being evaluatec

Plant 1 - Buildings 7, 25, 26, and X

Plant 2 - Buildings 41 and 508

DT-6 - Storage Building

DT-10 - Metal and Wood Storage Buildings

DT-14 - Horizontal beam between L-Shaped Building and Brick Warehouse

[d] Radiological COPCs in sewer sediment include the following: Ra-226, Ra-228, and U-238. Radiological COPCs in soil adjacent to sewers include the following: Ac-227, Pa-231, Ra-226, Ra-228, Th-230, and U-238.

[e] Although arsenic is identified as an inaccessible soil COPC at SLDS, Plant 2, Plant 6, and some properties, it is not being evaluated for the current industrial worker because all exposure pathways are incomplete due to the presence of ground cover that acts as a physical barrier to exposures.

[f] The background values presented in Table 4-1 are used as the EPCs for determination of the soil and sewer sediment dose and risk. Calculations of background dose and risk incorporate the same assumptions about ground cover as those applied to the corresponding receptor scenario.

[g] The scenarios identified for SLDS are for the sitewide evaluations, and include all ISOU sampling locations and properties.

[h] Recreational users are evaluated for exposures to inaccessible soils in DT-2 , DT-9 levee, and DT-15, through which the St. Louis Riverfront Trail passes. The St. Louis Riverfront Trail evaluation includes all three of these VPs combined.

[i] The floors inside of the north salt dome at DT-4 North and the storage building at DT-6 are currently earthen floors.

[j] West of Broadway Property Group consists of Plant 3, Plant 8, Plant 9, Plant 11, DT-20, DT-23, DT-27, DT-35, and DT-36.

[k] South of Angelrodt Property Group consists of DT-13, DT-14, DT-16, and DT-17.

"---" = No risk evaluation being performed for receptor at the identified property.

As - Arsenic; Cd - Cadmium; Pb - Lead

Table K-2A. Property-Wide Exposure Point Concentrations for Radiological Contaminants of Potential Concern for Inaccessible and Accessible Soil at Plant Properties, Industrial/Commercial Vicinity Properties, Railroad Properties, and Roadways

Property	Area (m^2)	Statistic	EPCs for Radiological COPC (pCi/g)										
			Ac-227	Pa-231	Pb-210 [a]	Ra-226	Ra-228	Th-228	Th-230	Th-232	U-234 [a]	U-235	U-238
Sitewide													
Background[b]	10,000	ISOU EPC	0.18	1.12	N/A	3.04	1.00	N/A	2.18	1.18	N/A	0.10	1.67
	10,000	Accessible EPC	0.18	1.12	N/A	3.04	1.00	1.26	2.18	1.18	N/A	0.10	1.67
SLDS (Sitewide)	381,357	ISOU EPC	0.81	0.83	4.97	3.82	0.90	N/A	7.33	1.00	11.72	0.64	11.72
	776,844	Accessible EPC	0.17	0.22	3.42	2.63	0.84	1.16	3.18	0.97	6.58	0.37	6.58
St. Louis Riverfront Trail	103,089	ISOU EPC	0.06	0.11	4.21	3.24	0.93	N/A	2.36	1.04	2.29	0.16	2.29
	269,387	Accessible EPC	0.21	0.23	3.41	2.62	0.87	1.18	4.01	1.01	2.55	0.16	2.55
Mallinckrodt Properties													
Plant 1	10,500	ISOU EPC	1.32	1.27	21.53	16.56	0.91	N/A	18.23	0.99	23.97	1.28	23.97
	11,700	Accessible EPC	0.20	0.90	3.72	2.86	0.95	1.26	3.17	1.37	4.49	0.31	4.49
Plant 2	3,563	ISOU EPC	0.12	0.18	2.94	2.26	1.12	N/A	3.22	1.28	23.45	2.08	23.45
	16,531	Accessible EPC	0.14	1.03	3.74	2.88	0.95	1.3	1.94	1.09	3.45	0.08	3.45
Plant 6	2,370	ISOU EPC	1.33	1.31	10.79	8.30	0.80	N/A	5.93	0.96	171.40	11.28	171.40
	29,965	Accessible EPC	0.39	0.40	3.87	2.98	0.89	1.29	4.27	1.08	17.49	0.95	17.49
Mallinckrodt Security Gate 49	5	ISOU EPC	0.21	0.38	6.97	5.36	0.96	N/A	4.9	1.13	8.54	0.40	8.54
	435	Accessible EPC	0.44	0.54	3.86	2.97	0.75	1.04	3.52	0.92	5.59	0.44	5.59
Industrial/Commercial Vicinity Properties													
DT-2	12,665	ISOU EPC	0.09	0.14	5.67	4.36	0.96	N/A	2.84	1.07	2.89	0.22	2.89
	77,475	Accessible EPC	0.29	0.24	3.63	2.79	0.89	1.24	4.88	1.07	2.92	0.18	2.92
DT-4	7,962	ISOU EPC	9.54	9.94	12.51	9.62	1.07	N/A	65.42	1.23	83.46	4.62	83.46
	6,178	Accessible EPC	0.29	0.57	4.13	3.18	0.90	1.22	3.91	0.99	12.30	0.70	12.30
DT-6	3,582	ISOU EPC	6.86	7.19	6.57	5.05	0.87	N/A	25.30	1.03	26.11	1.86	26.11
	6,686	Accessible EPC	0.22	0.34	3.67	2.83	0.93	1.53	3.93	1.12	4.14	0.34	4.14
DT-8	20,471	ISOU EPC	0.12	0.15	3.46	2.66	0.81	N/A	2.23	0.88	3.22	0.20	3.22
	85,560	Accessible EPC	0.13	0.23	4.03	3.10	0.87	1.14	3.01	0.98	5.27	0.29	5.27
DT-10	726	ISOU EPC	0.28	0.15	5.77	4.44	1.00	N/A	4.18	0.97	7.55	0.66	7.55
	10,479	Accessible EPC	0.24	0.37	5.72	4.40	1.13	1.48	4.37	1.20	8.28	0.49	8.28
DT-29	533	ISOU EPC	0.01	0.25	1.47	1.13	0.81	N/A	1.45	1.05	1.76	0.26	1.76
	1,345	Accessible EPC	1.19	0.87	4.04	3.11	0.85	1.27	3.30	0.95	20.07	1.16	20.07
DT-34	4,780	ISOU EPC	0.07	0.16	3.08	2.37	0.93	N/A	2.86	1.46	1.87	0.06	1.87
	9,846	Accessible EPC	0.01	0.10	2.31	1.78	0.83	0.95	1.79	0.86	1.66	0.14	1.66
West of Broadway	33,043	ISOU EPC	0.12	0.34	2.82	2.17	0.78	N/A	2.34	0.88	2.42	0.19	2.42
	50,847	Accessible EPC	0.12	0.27	3.03	2.33	0.94	1.3	3.16	1.02	2.41	0.17	2.41
South of Angelrodt	6,508	ISOU EPC	0.19	0.26	3.68	2.83	0.89	N/A	2.81	0.93	3.38	0.22	3.38
	34,159	Accessible EPC	0.14	0.25	3.32	2.55	0.80	1.04	2.66	0.91	3.15	0.20	3.15

Table K-2A. Property-Wide Exposure Point Concentrations for Radiological Contaminants of Potential Concern for Inaccessible and Accessible Soil at Plant Properties, Industrial/Commercial Vicinity Properties, Railroad Properties, and Roadways

Property	Area (m^2)	Statistic	EPCs for Radiological COPC (pCi/g)										
			Ac-227	Pa-231	Pb-210 [a]	Ra-226	Ra-228	Th-228	Th-230	Th-232	U-234 [a]	U-235	U-238
Railroad Properties													
DT-3	6,363	ISOU EPC	0.12	0.16	3.74	2.88	1.57	N/A	3.23	1.43	4.32	0.27	4.32
	13,562	Accessible EPC	0.48	0.54	4.15	3.19	0.84	1.09	4.11	0.93	7.33	0.47	7.33
DT-9 Rail Yard	24,384	ISOU EPC	0.53	0.66	14.34	11.03	1.03	N/A	12.27	1.11	10.16	0.67	10.16
	131,791	Accessible EPC	0.07	0.20	4.13	3.18	0.89	1.27	3.01	1.07	2.93	0.18	2.93
DT-9 Levee	84,920	ISOU EPC	0.05	0.07	1.90	1.46	0.91	N/A	1.52	1.02	1.59	0.10	1.59
	188,158	Accessible EPC	0.08	0.34	3.67	2.82	0.86	1.13	2.25	0.94	2.14	0.17	2.14
DT-9 Main Line	36,630	ISOU EPC	0.08	0.17	3.29	2.53	1.46	N/A	3.19	1.59	2.43	0.16	2.43
	16,803	Accessible EPC	0.09	0.17	3.29	2.53	0.76	1.06	2.66	0.94	2.37	0.17	2.37
DT-9 Soil Spoils	10,636	ISOU EPC	1.02	1.31	5.63	4.33	0.80	N/A	30.13	0.86	20.93	1.05	20.93
	68,803	Accessible EPC	0.01	0.39	3.59	2.76	0.87	1.13	2.59	0.98	2.49	0.20	2.49
DT-12	23,009	ISOU EPC	0.08	0.08	2.95	2.27	0.67	N/A	4.59	0.76	3.45	0.21	3.45
	13,730	Accessible EPC	0.09	0.28	3.63	2.79	0.86	1.12	4.43	1.01	4.89	0.30	4.89
DT-15	5,505	ISOU EPC	0.05	0.42	2.91	2.24	0.95	N/A	2.29	1.09	2.17	0.19	2.17
	3,754	Accessible EPC	0.05	0.20	2.33	1.79	0.72	0.91	1.87	0.76	1.38	0.03	1.38
Roadways													
Angelrodt Street	7,696	ISOU EPC	0.16	0.44	4.06	3.12	0.79	N/A	3.28	0.92	3.20	0.22	3.20
Bremen Avenue	10,920	ISOU EPC	1.93	2.15	1.92	1.48	1.02	N/A	8.70	1.02	111.60	5.63	111.60
Buchanan Street	7,193	ISOU EPC	2.11	2.21	4.54	3.49	0.95	N/A	8.12	0.99	36.79	2.02	36.79
Destrehan Street	4,772	ISOU EPC	0.12	0.17	4.17	3.21	0.85	N/A	11.03	1.16	6.49	0.34	6.49
Hall Street	33,810	ISOU EPC	0.77	0.79	5.82	4.48	0.82	N/A	6.05	0.95	8.40	0.50	8.40
Mallinckrodt Street	5,391	ISOU EPC	0.26	0.56	2.08	1.60	0.77	N/A	3.15	1.25	6.38	0.35	6.38
North Second Street	10,552	ISOU EPC	0.48	0.57	3.82	2.94	0.86	N/A	5.17	1.05	6.11	0.38	6.11
Salisbury Street	2,207	ISOU EPC	0.10	0.08	2.02	1.55	0.73	N/A	1.56	0.87	1.33	0.08	1.33

[a] EPC was determined based upon Table 2.15 of the 1993 BRA (DOE 1993).

[b] EPCs for background soil were determined based upon 95% UCL values in Table 3-2 of the *Background Soils Characterization Report for the St. Louis Downtown Site* (USACE 1999a).

N/A - Not Available

Table K-2B. Sitewide and Property-Specific Exposure Point Concentrations for Metal Contaminants of Potential Concern in Inaccessible Soil and Accessible Soil within the Former Uranium-Ore Processing Area

Property	Inaccessible Soil EPCs (mg/kg)	Accessible Soil EPCs (mg/kg)		
	Arsenic	Arsenic	Cadmium	Uranium [a]
Background	10.6	10.6	1.03	NA
SLDS (Sitewide)	93.99	14.93	1.019	NA
Mallinckrodt Properties				
Plant 2 [b]	8.49	16.57	4.554	NA
Plant 6 [c]	9.578	15.36	1.071	NA
Industrial/Commercial Vicinity Properties				
DT-10 [d]	162.5	46.7	1.4	NA
Railroad Vicinity Properties				
DT-9 Main Line	8.17	NA	NA	NA
DT-12	166.8	NA	NA	NA
Roadway Vicinity Properties				
Hall Street	12.56	NA	NA	NA
Mallinckrodt Street	14.8	NA	NA	NA
Destrehan Street	16.98	NA	NA	NA

[a] Uranium metal was not retained as a COPC in inaccessible soil and was not evaluated in the PRARs for the properties shown in the above table; therefore, uranium metal is not being evaluated for inaccessible and accessible soil dose and risk, even though it was identified as a COC in the 1998 ROD.

[b] No Accessible soil EPCs or risks were calculated in the Plant 2 PRAR (USACE 2002) for arsenic or cadmium; however, EPCs and risks for these metals in accessible soil are being calcualted in this BRA to determine property-wide risks.

[c] Accessible soil EPCs for arsenic and cadmium were 18.02 and 1.04 mg/kg, respectively, in the Plant 6 PRAR. The differences between the the above arsenic and cadmium EPCs versus those in the PRAR are due to the incorporation of data into the calculations of the above EPCs that became available after the PRAR was developed. The accessible soil EPC calculated for uranium metal is 21.02 mg/kg; however, because uranium metal was not identified as an inaccessible soil COPC, and no accessible soil EPCs were calculated for uranium metal in the Plant 6 PRAR, uranium metal is not being evaluated for combined inaccessible/accessible soil dose and risk.

[d] The accessible soil EPCs for arsenic and cadmium in the table are the same as those used in the DT-10 PRAR (USACE 2008).

NA - No accessible soil areas exist on RR or roadway VPs.

Table K-3A. St. Louis Downtown Site-Specific Soil Activity Fractions

Radiological COPC	Soil Concentration [a] (pCi/g)	Activity Fraction
Ac-227	15	0.022
Pa-231	14	0.021
Pb-210	50	0.074
Ra-226	38	0.056
Ra-228	4.7	0.007
Th-228	5.8	0.009
Th-230	90	0.134
Th-232	5.8	0.009
U-234	220	0.327
U-235	10	0.015
U-238	220	0.327
TOTAL	**673.3**	**1**

[a] Soil concentrations used to determine activity fractions are from Table 3.9 of the 1993 BRA (DOE 1993).

Table K-3B. Exposure Point Concentrations for Radiological Contaminants of Potential Concern on Interior Building Surfaces

Property	EPCs for Radiological COPC (pCi/m^2)										
	Ac-227	**Pa-231**	**Pb-210** [a]	**Ra-226**	**Ra-228**	**Th-228**	**Th-230**	**Th-232**	**U-234** [a]	**U-235**	**U-238**
Sitewide											
Plant 1 Building 7	164	153	546	415	51	63	983	63	2404	109	2404
Plant 1 Building 26	173	162	577	439	54	67	1039	67	2540	115	2540
Plant 2 Building 41	165	165	549	417	52	64	987	64	2414	110	2414
Plant 2 Building 508	155	145	516	393	49	60	930	60	2273	103	2273
DT-6 Storage Building	84	79	281	213	26	33	506	33	1236	56	1236
DT-10 Metal Storage Building	140	131	467	355	44	54	841	54	2055	93	2055
DT-10 Wood Storage Building	68	64	227	173	21	26	409	26	1001	45	1001

[a] EPC was determined based upon Table 2.15 of the 1993 BRA (DOE 1993).

A conservative estimation of 180 m^2 of contaminated surfaces was used for each structure to determine the risk and dose.

Table K-3C. Exposure Point Concentrations for Radiological Contaminants of Potential Concern on Exterior Building Surfaces

Property	**EPCs for Radiological COPC (pCi/m^2)**										
	Ac-227	**Pa-231**	**Pb-210** [a]	**Ra-226**	**Ra-228**	**Th-228**	**Th-230**	**Th-232**	**U-234** [a]	**U-235**	**U-238**
Sitewide											
Plant 1 Building 25	1,113	1,039	3,710	2,819	349	430	6,677	430	16,323	742	16,323
Plantt 1 Building X	426	398	1,421	1,080	134	165	2,557	165	6,251	284	6,251
DT-10 Wood Storage Building	3,973	3,708	13,243	10,065	1,245	1,536	23,838	1,536	58,270	2,649	58,270
DT-14	563	525	1,887	1,877	176	218	3,378	218	8,257	375	8,257

[a] EPC was determined based upon Table 2.15 of the 1993 BRA (DOE 1993).

A conservative estimation of 180 m^2 of contaminated surfaces was used for each structure to determine the risk and dose.

Table K-4A. Exposure Point Concentrations for Radiological Contaminants of Potential Concern Identified in Sewer Sediment by Sampling Location

Property	Station ID	EPCs for Radiological COPCs (pCi/g)		
		Ra-226	Ra-228	U-238
Background [a]	N/A	1.007	0.466	1.378
SLDS (Sitewide)	N/A	**1.06**	**0.35**	**3.95**
Plant 1	SLD123489	0.97	0.37	1.56
	SLD123490	0.81	0.50	0.85
	SLD123491	1.63	0.81	0.84
	SLD123492	1.05	0.40	1.53
	SLD123493	0.74	0.26	1.90
	SLD123494	2.14	0.23	0.87
	SLD123495	0.67	0.14	1.10
	SLD123496	0.88	0.28	13.60
	SLD123497	1.45	0.28	1.50
	SLD123498	0.77	0.20	2.40
Plant 2	SLD123503	0.43	0.23	0.79
	SLD123504	0.84	0.25	-1.46
	SLD123505	0.84	0.17	0.79
	SLD123740	0.82	0.21	0.59
	SLD123741	0.60	0.36	-0.02
	SLD123742	1.14	0.56	2.10
	SLD123743	0.92	0.19	0.62
	SLD123744	0.92	0.18	0.76
	SLD123749	0.80	0.16	0.35
	SLD123750	0.87	0.24	0.59
	SLD123751	0.85	0.19	0.79
Plant 6	SLD123746	1.22	0.42	6.04
	SLD123747	0.83	0.27	0.90
	SLD123748	0.90	0.20	0.93
Plant 7	SLD123745	0.89	0.48	1.02
DT-11	SLD123488	0.61	0.27	0.70

[a] EPCs for background sediment were determined based upon 95% UCL values in Table I-4 of Appendix I.

N/A - Not Applicable

Table K-4B. Exposure Point Concentrations for Arsenic Identified in Sewer Sediment by Sampling Location

Property	Sewer Sediment Location	EPC [a] (mg/kg)
Background	All Locations Combined	11.84
SLDS (Sitewide)	All Locations Combined	4.846
Plant 1	SLD123489	5.90
	SLD123490	9.10
	SLD123492	5.10
	SLD123493	6.80
	SLD123494	4.20
	SLD123495	2.70
	SLD123496	17.10
	SLD123497	2.20
	SLD123498	2.80
Plant 2	SLD123503	4.30
	SLD123504	3.80
	SLD123505	4.20
	SLD123740	1.90
	SLD123742	3.90
	SLD123743	1.70
	SLD123744	2.10
	SLD123749	1.30
	SLD123750	2.80
Plant 6	SLD123746	1.80
	SLD123747	1.00
	SLD123748	2.60
Plant 7	SLD123745	4.60
DT-11	SLD123488	3.90

[a] The arsenic EPC for each individual location is the concentration reported at each location. All arsenic concentrations are detected concentrations.

Table K-5A. Exposure Point Concentrations for Radiological Contaminants of Potential Concern Identified in Soil Adjacent to Sewer Lines by Property/Borehole Location

Property	Station ID	EPCs for Radiological COPCs (pCi/g)					
		Ac-227	Pa-231	Ra-226	Ra-228	Th-230	U-238
Background[a]	N/A	0.18	1.12	3.04	1.00	2.18	1.67
SLDS (Sitewide)	N/A	**7.01**	**8.11**	**8.43**	**0.91**	**456.50**	**14.23**
Plant 1	SLD124538	0.13	-0.02	1.61	1.26	1.98	2.70
	SLD124540	2.11	1.50	4.66	1.08	24.00	78.60
	SLD124542	-0.03	0.12	1.68	0.96	1.53	1.69
	SLD124544	0.27	0.47	2.97	0.98	2.84	16.30
	SLD124546	0.27	0.05	1.70	1.23	1.89	1.20
	SLD124548	-0.02	1.51	2.31	0.98	1.76	1.61
	SLD124550	0.20	0.12	2.15	0.97	1.73	2.94
	SLD124552	0.15	0.42	1.37	1.09	1.23	1.81
	SLD124554	0.13	0.03	1.33	0.96	1.75	1.24
	SLD124556	0.01	0.02	1.98	0.57	1.20	1.56
	SLD124558	-0.07	0.40	1.64	0.91	1.51	1.49
	SLD124560	0.11	0.51	2.20	1.02	1.88	2.27
	SLD124564	0.31	0.73	1.77	1.07	1.16	1.02
	SLD124566	0.15	0.55	2.41	1.08	2.13	2.92
	SLD124568	0.18	1.03	1.44	1.02	1.40	1.94
	SLD124570	0.27	0.00	2.29	1.03	2.33	2.33
	SLD125283	0.09	0.24	2.24	0.96	2.64	1.38
	SLD125521	0.39	-0.12	5.49	0.98	3.55	4.22
Plant 2	SLD124574	0.20	0.45	1.79	1.28	1.64	3.68
	SLD124576	0.27	-0.13	1.87	0.85	1.56	1.96
	SLD124578	-0.09	0.16	1.60	0.71	1.63	8.42
	SLD125385	0.32	0.61	2.26	1.41	2.23	26.90
Plant 6	HTZ88929	44.80	56.30	58.30	1.16	489.00	3.69
	HTZ88930	3.94	3.14	20.20	0.87	72.60	2.69
	SLD127572	0.30	0.65	9.02	1.09	5.25	14.50
Plant 7/DT-12	SLD124586	0.09	1.70	1.95	1.21	2.57	20.40
	SLD131146	0.22	0.54	5.14	1.06	33.50	13.40
	SLD131156	0.12	0.23	3.62	1.07	7.13	7.97
	SLD131166	0.24	0.38	1.93	1.09	2.12	2.35
	SLD131176	0.24	0.14	4.65	1.12	3.75	3.16
	SLD93275	153.00	170.00	117.00	2.56	10180.00	48.70
	SLD93276	21.40	23.70	32.60	1.13	2961.00	16.10
	SLD93277	76.90	102.00	44.70	0.76	4533.00	13.40
DT-2 Levee	SLD120945	11.60	14.10	45.20	1.55	1097.00	22.40
	SLD120946	6.93	7.12	35.30	1.19	738.00	18.90
	SLD120947	5.68	7.09	32.90	1.09	1180.00	35.30
	SLD120948	0.57	0.70	4.35	0.89	47.30	3.82
DT-8 and DT-11	SLD124590	0.25	0.40	2.19	1.01	1.86	0.56
	SLD124592	-0.03	0.24	1.12	0.73	1.24	1.65
	SLD124594	0.08	0.92	1.59	1.20	1.57	1.08

[a] EPCs for background soil were determined based upon 95% UCL values in Table 3-2 of the *Background Soils Characterization Report for the St. Louis Downtown Site* (USACE 1999a).

N/A - Not Applicable

Table K-5B. Exposure Point Concentrations for Metal Contaminants of Potential Concern Identified in Soil Adjacent to Sewer Lines by Property/Borehole Location

Property	Station Name	Sewer Soil EPCs (mg/kg) [a]		
		Arsenic	Cadmium	Lead
Background	All Locations Combined	10.6	1.03	209
SLDS (Sitewide) [b]	All Locations Combined	19.3	122	271
Plant 1	SLD124538	4.4 [c]	1	18.7
	SLD124540	94.8	33.8	715
	SLD124542	5	0.26	49.2
	SLD124544	10.7	1.3	41.1
	SLD124546	60.9	2.7	16.2
	SLD124548	20.9	1,730	176
	SLD124550	13.2	1.3	102
	SLD124552	18.3	1	17
	SLD124554	8	28.8	23.5
	SLD124556	10.1	6.4	125
	SLD124558	15.1	0.78	36.8
	SLD124560	22.1	5.6	352
	SLD124564	6.4	2.5	12.7
	SLD124566	17.3	0.63 [c]	39.8
	SLD124568	8.1	0.83	13.7
	SLD124570	41.9	0.84	476
	SLD125283	4.2 [c]	0.83	14.3
	SLD125521	31.8	28.9	345
Plant 2	SLD124574	7.6	2.2	13.1
	SLD124576	2.5	1.2 [c]	3,380
	SLD124578	9.3	0.65 [c]	14.0
	SLD125385	17.3	1.6	61.7
Plant 6	SLD124572	11	0.63 [c]	595
Plant 7N/BNSF RR	SLD124586	7.2	17.2	148
DT-8 & DT-11	SLD124590	4 [c]	0.84	12.1
	SLD124592	3.4	0.49	6
	SLD124594	9.2	0.67 [c]	10.9

[a] Each EPC for arsenic and cadmium is the lesser of the maximum detection and the 95% UCL. Each EPC for lead is the mean concentration per USEPA (2003b).

[b] Start and end depths for sitewide evaluation are the shallowest and deepest depth intervals, respectively, that were sampled across all soil boreholes adjacent to sewers at SLDS.

[c] Value is a non-detect result, but is being used to determine risk at the level of the reported detection limit.

Table K-6. Input Values for Non-Default Residual Radioactivity Model Parameters

Parameter	Unit	RESRAD Default [a]	Current & Future Industrial Worker	Construction/ Utility Worker/Sewer Maintenance Worker	Recreational User
Soil Concentrations/Transport Factors					
Soil Concentrations	pCi/g	NA	Table K-2A	Table K-2A	Table K-2A
Contaminated Zone Parameters					
Area of Contaminated Zone	m^2	10,000	Property-specific	Property-Specific/180 [b]	Property-specific
Thickness of Contaminated Zone (All Properties)	m	2	2	2	2
Cover/Hydrological Data					
Cover Depth	m	0	0.3048/1.0/0 [c]	0	1.0/0 [d]
Density of Cover Material	g/cm^3	1.5	1.5/Not used [c]	Not used	1.5/Not used [d]
Cover Erosion Rate	m/year	0.001	0.00006/Not used [c]	Not used	0.00006/Not used [d]
Density of Contaminated Zone	g/cm^3	1.5	1.28	1.28	1.5
Contaminated Zone Erosion Rate	m/year	0.001	0.00006	0.00006	0.00006
Contaminated Zone Total Porosity	unitless	0.40	0.42	0.42	0.40
Contaminated Zone Field Capacity	unitless	0.20	0.36	0.36	0.20
Contaminated Zone Hydraulic Conductivity	m/yr	10.00	3.048	3.048	10.00
Contaminated Zone B Parameter	unitless	5.30	10.40	10.40	5.30
Wind Speed	m/sec	2.00	4.17	4.17	2.00
Precipitation	m/yr	1.00	0.92	0.92	1.00
Irrigation	m/yr	0.20	0.00	0.00	0.20
Runoff Coefficient	unitless	0.20	0.80	0.80	0.20
Occupancy Data					
Inhalation Rate	m^3/year	8,400	10,550	10,550	9,326
Mass Loading for Inhalation	g/m^2	0.0001	0.0002	0.0002	0.0001
Indoor Dust Filtration Factor	unitless	0.4	0.5	0.5	0.4
Exposure Duration	year	30	25	1	9
Indoor Time Fraction	unitless	0.5	0.1969	0	0
Outdoor Time Fraction	unitless	0.25	0.04566	0.082/0.0091/ 0.00091 [e]	0.0086
Ingestion Dietary Data					
Soil Ingestion Rate	g/year	36.5	49.64	175.2	18.25
Pathways					
External Gamma	unitless	Active	Active	Active	Active
Inhalation	unitless	Active	Active	Active [f]	Active
Plant Ingestion	unitless	Active	Suppressed	Suppressed	Suppressed
Meat Ingestion	unitless	Active	Suppressed	Suppressed	Suppressed
Milk Ingestion	unitless	Active	Suppressed	Suppressed	Suppressed
Aquatic Foods	unitless	Active	Suppressed	Suppressed	Suppressed
Drinking Water	unitless	Active	Suppressed	Suppressed	Suppressed
Soil Ingestion	unitless	Active	Active	Active	Active
Radon	unitless	Suppressed	Suppressed	Suppressed	Suppressed

[a] Where possible, input values for the RESRAD models equate to USEPA assumptions applied to the metals evaluations.

[b] Area of contaminated zone is assumed to be 180 m^2 for a sewer maintenance worker and utility worker working adjacent to sewer lines, and is property-specific for all other construction worker and utility worker receptor scenarios.

[c] The current industrial worker scenario for the SLDS ISOU assumes a 1-foot thick soil cover is in place, with the exception of levee properties DT-2, DT-9 Levee, and DT-15 where the levee is represented by assuming a 1-meter thick soil cover is in place. The future industrial worker scenario for the SLDS ISOU and for the accessible soil scenario assumes no cover is in place.

[d] The current and future recreational user for the SLDS ISOU assumes a 1-meter thick soil cover is present, representing the levee. Dose and risk for the accessible soil recreational user scenario assumes no ground cover.

[e] Outdoor time fraction is 0.082 for a construction worker (720 hours/year) and 0.0091 for a utility worker exposed to soil adjacent to sewers (80 hours/year) and 0.00091 for a sewer maintenance worker exposed to sediment inside of sewers (8 hours/year).

[f] Inhalation is not active for evaluating sewer maintenance worker exposures to sewer sediment because it's assumed that the moisture content of the sediment will prevent emissions into the air and subsequent inhalation.

NA = Parameter is not applicable to receptor scenario.

Table K-7. Input Values for Non-Default Residual Radioactivity-Build Model Parameters

Parameter	Unit	RESRAD-Build Default	Industrial Worker	Maintenance Worker
Case				
Dose/Risk Library	NA	FGR 11	FGR 11	FGR 11
Time Parameters				
Exposure Duration	days	365	9125	9125
Indoor Fraction	unitless	0.5	0.23	0.0091
Building Parameters				
Number of Rooms	NA	1	1	1
Area	m^2	36	100	100
Receptor Parameters				
Number of Receptors	unitless	1	1	1
Time Fraction	unitless	1	1	1
Breathing Rate	m^3/day	18	33.6	33.6
Location (x,y,z)	m	1,1,1	5, 5, 1	5, 5, 1
Shielding Parameters				
Source Parameters				
Number of Sources	unitless	1	5	5
Type	unitless	Volume	Area	Area
Direction	unitless	X	Floor (z), four walls (x,y,x,y)	Floor (z), four walls (x,y,x,y)
Location (x,y,z)	m	0,0,0	Floor: 5, 5, 0;	Floor: 5, 5, 0;
			Walls: 10, 5, 1	Walls: 10, 5, 1
			5, 10, 1	5, 10, 1
			0, 5, 1;	0, 5, 1;
			5, 0, 1	5, 0, 1
Geometry (circular or rectangle)	NA	Circular	Circular	Circular
Area (volume, area, point source)	m^2	36	100, 20, 20, 20, 20	100, 20, 20, 20, 20
Release				
Air Fraction (all sources)	NA	0.1	0.07	0.07
Direct Ingestion (all sources)	1/h	0	0	0
Removable Fraction (area, line, point source)	unitless	0.5	0.2	0.2
Lifetime (area, line, point source)	days	365	10,000	10,000
Pathways				
External	NA	Active	Active	Active
Inhalation	NA	Active	Active	Active
Ingestion	NA	Active	Active	Active

FGR = Federal Guidance Report.

Table K-8. Input Values for Pathway Dose Equations: Exposures to Metal Contaminants of Potential Concern

Exposure Pathway	Exposure Parameter	Exposure Parameter Description	Units	Exposure Parameter Value	Source/Comments
General Assumptions - All Pathways	BW_a	Adult Body Weight	kg	71.8	USEPA (1997a)
	ED_{cw}	Exposure Duration for Construction Worker	years	1	USEPA (1997a)
	ED_{iw}	Exposure Duration for Industrial Worker	years	25	USEPA (1997a)
	ED_{mw}	Exposure Duration for Sewer Maintenance Worker	years	25	USEPA (1997a)
	ED_{uw}	Exposure Duration for Utility Worker	years	1	USEPA (1989a)
	EF_{cw-sl}	Soil Exposure Frequency for Construction Worker	days/year	90	Exposure frequency applied to road workers at North St. Louis County FUSRAP sites.
	EF_{iw-sl}	Soil Exposure Frequency for Industrial Worker	days/year	50	USACE (1998b). Exposure frequency corresponds to 400 hours assumed for time spent outdoors.
	EF_{mw-sd}	Sediment Exposure Frequency for Sewer Maintenance Worker	days/year	1	Conservative estimate of exposure frequency for a City sewer worker at one manhole location.
	EF_{uw-sl}	Exposure Frequency for Utility Worker	days/year	10	USACE (1998b) exposure frequency assumed to be a one-time 80-hour exposure.
Soil/Sediment Ingestion	FI_{cw-sl}	Fraction Contaminated Soil Ingested by Construction Worker	unitless	1	USEPA (1989a)
	FI_{iw-sl}	Fraction Contaminated Soil Ingested by Industrial Worker	unitless	1	USEPA (1989a)
	FI_{mw-sd}	Fraction Contaminated Sediment Ingested by Sewer Maintenance Worker	unitless	1	USEPA (1989a)
	FI_{uw-sl}	Fraction Contaminated Soil Ingested by Utility Worker	unitless	1	USEPA (1989a)
	IR_{cw-sl}	Soil Ingestion Rate for Construction Worker	mg/day	480	USEPA (1996a, 2002b)
	IR_{iw-sl}	Soil Ingestion Rate for Industrial Worker	mg/day	136	USACE (1998b)
	IR_{mw-sd}	Sediment Ingestion Rate for Sewer Maintenance Worker	mg/day	330	USACE (1996a, 2002b)
	IR_{uw-sl}	Soil Ingestion Rate for Utility Worker	mg/day	480	USEPA (1996a, 2002b)
	AT_{c-ing}	Carcinogenic Averaging Time for All Receptors	days	25,550	Calculated value per USEPA (1989a): $AT_{c-ing} = 70\ years \times 365 \frac{days}{year}$
	$AT_{cw-nc-ing}$	Noncarcinogenic Averaging Time for Construction Worker	days	365	Calculated value per USEPA (1989a): $AT_{cw-nc-ing} = ED_{uw} \times 365 \frac{days}{year}$
	$AT_{iw-nc-ing}$	Noncarcinogenic Averaging Time for Industrial Worker	days	9,125	Calculated value per USEPA (1989a): $AT_{iw-nc-ing} = ED_{iw} \times 365 \frac{days}{year}$
	$AT_{mw-nc-ing}$	Noncarcinogenic Averaging Time for Sewer Maintenance Worker	days	9,125	Calculated value per USEPA (1989a): $AT_{mw-nc-ing} = ED_{mw} \times 365 \frac{days}{year}$
	$AT_{uw-nc-ing}$	Noncarcinogenic Averaging Time for Utility Worker	days	365	Calculated value per USEPA (1989a): $AT_{uw-nc-ing} = ED_{uw} \times 365 \frac{days}{year}$

Table K-8. Input Values for Pathway Dose Equations: Exposures to Metal Contaminants of Potential Concern

Exposure Pathway	Exposure Parameter	Exposure Parameter Description	Units	Exposure Parameter Value	Source/Comments
Soil/Sediment - Dermal Absorption	ABS	Dermal Absorption Factors (ABS) for All Receptors Being Evaluated:			
		Arsenic	unitless	0.03	USEPA (2004)
		Cadmium	unitless	0.001	USEPA (2004)
	AF_{cw-sl}	Soil-Skin Adherence Factor for Construction Worker	mg/cm^2-event	0.3	USEPA (2004)
	AF_{iw-sl}	Soil-Skin Adherence Factor for Industrial Worker	mg/cm^2-event	0.3	USEPA (2004)
	AF_{mw-sd}	Sediment-Skin Adherence Factor for Sewer Maintenance Worker	mg/cm^2-event	13	USEPA (2004)
	AF_{uw-sl}	Soil-Skin Adherence Factor for Utility Worker	mg/cm^2-event	0.3	USEPA (2004)
	EV_{cw-sl}	Soil Contact Event Frequency – Construction Worker	events/day	1	USEPA (2004)
	EV_{iw-sl}	Soil Contact Event Frequency – Industrial Worker	events/day	1	USEPA (2004)
	EV_{mw-sd}	Sediment Contact Event Frequency – Sewer Maintenance Worker	events/day	1	USEPA (2004)
	EV_{uw-sl}	Soil Contact Event Frequency Contact for Utility Worker	events/day	1	USEPA (2004)
	SA_{cw-sl}	Skin Surface Area Available for Soil Contact for Construction Worker	cm^2/day	3,890	Calculated value for outdoor worker per USEPA (2011), Table 7-12 - sum of 50th percentile values for head, forearms, and hands for a male worker.
	SA_{iw-sl}	Skin Surface Area Available for Soil Contact for Industrial Worker	cm^2/day	3,890	Calculated value for outdoor worker per USEPA (2011), Table 7-12 - sum of 50th percentile values for head, forearms, and hands for a male worker.
	SA_{mw-sd}	Skin Surface Area Available for Sediment Contact for Sewer Maintenance Worker	cm^2/day	3,890	Calculated value for outdoor worker per USEPA (2011), Table 7-12 - sum of 50th percentile values for head, forearms, and hands for a male worker.
	SA_{uw-sl}	Skin Surface Area Available for Sediment Contact for Utility Worker	cm^2/day	3,890	Calculated value for outdoor worker per USEPA (2011), Table 7-12 - sum of 50th percentile values for head, forearms, and hands for a male worker.
	AT_{c-derm}	Carcinogenic Averaging Time for All Receptors	days	25,550	Calculated value per USEPA (1989a): $AT_{c-derm} = 70\ years \times 365\ \frac{days}{year}$
	$AT_{cw-nc-derm}$	Noncarcinogenic Averaging Time for Construction Worker	days	365	Calculated value per USEPA (1989a): $AT_{cw-nc-ing} = ED_{uw} \times 365\ \frac{days}{year}$
	$AT_{iw-nc-derm}$	Noncarcinogenic Averaging Time for Industrial Worker	days	9,125	Calculated value per USEPA (1989a): $AT_{iw-nc-derm} = ED_{iw} \times 365\ \frac{days}{year}$
	$AT_{mw-nc-derm}$	Noncarcinogenic Averaging Time for Sewer Maintenance Worker	days	9,125	Calculated value per USEPA (1989a): $AT_{mw-nc-derm} = ED_{mw} \times 365\ \frac{days}{year}$
	$AT_{uw-nc-derm}$	Noncarcinogenic Averaging Time for Utility Worker	days	365	Calculated value per USEPA (1989a): $AT_{uw-nc-derm} = ED_{uw} \times 365\ \frac{days}{year}$
Soil - Inhalation	$ET_{cw-sl-inh}$	Soil Exposure Time for Construction Worker	hr/day	8	RAIS (DOE 2011), assumption based on length of work day
	$ET_{iw-sl-inh}$	Soil Exposure Time for Industrial Worker	hr/day	8	RAIS (DOE 2011), assumption based on length of work day
	$ET_{uw-sl-inh}$	Soil Exposure Time for Utility Worker	hr/day	8	RAIS (DOE 2011), assumption based on length of work day
	PEF_{cw}	Particulate Emission Factor for Construction Worker	m^3/kg	6.58×10^8	Calculated value per USEPA (2002b). Value assumes 0% vegetative cover of the site
	PEF_{iw}	Particulate Emission Factor for Industrial Worker	m^3/kg	1.36×10^9	USEPA (2002b). Default value for industrial worker.
	PEF_{uw}	Particulate Emission Factor for Utility Worker	m^3/kg	6.58×10^8	Calculated value per USEPA (2002b). Value assumes 0% vegetative cover of the site
	AT_{c-inh}	Carcinogenic Averaging Time for All Receptors	hr	613,200	Calculated value per USEPA (2009b): $AT_{c-inh} = 70\ years \times 365\ \frac{days}{year} \times 24\ \frac{hr}{day}$
	$AT_{cw-nc-inh}$	Noncarcinogenic Averaging Time for Construction Worker	hr	8,760	Calculated value per USEPA (2009b): $AT_{iw-nc-inh} = ED_{iw} \times 365\ \frac{days}{year} \times 24\ \frac{hr}{day}$
	$AT_{iw-nc-inh}$	Noncarcinogenic Averaging Time for Industrial Worker	hr	219,000	Calculated value per USEPA (2009b): $AT_{iw-nc-inh} = ED_{iw} \times 365\ \frac{days}{year} \times 24\ \frac{hr}{day}$
	$AT_{uw-nc-inh}$	Noncarcinogenic Averaging Time for Utility Worker	hr	8,760	Calculated value per USEPA (2009b): $AT_{uw-nc-inh} = ED_{uw} \times 365\ \frac{days}{year} \times 24\ \frac{hr}{day}$

Table K-9. Cancer Slope Factors for Radiological Contaminants of Potential Concern

CAS Number	Isotope	Radioactive Half-Life	ICRP Lung Type	GI Absorption Fraction	Water Ingestion	Food Ingestion	Soil Ingestion	Inhalation	External Exposure	Source
		years		Risk/pCi					Risk/yr per pCi/g	
14952-40-0	Ac-227+D	2.18E+01	S	5.00E-04	4.86E-10	6.53E-10	1.16E-09	2.09E-07	1.47E-06	FGR-13 Morbidity [a]
14331-85-2	Pa-231	3.28E+04	S	5.00E-04	1.73E-10	2.26E-10	3.74E-10	4.55E-08	1.39E-07	FGR-13 Morbidity [a]
14255-04-0	Pb-210+D	2.23E+01	M	2.00E-01	1.27E-09	3.44E-09	2.66E-09	1.39E-08	4.21E-09	FGR-13 Morbidity [a]
13982-63-3	Ra-226+D	1.60E+03	M	2.00E-01	3.86E-10	5.15E-10	7.30E-10	1.16E-08	8.49E-06	FGR-13 Morbidity [a]
15262-20-1	Ra-228+D	5.75E+00	M	2.00E-01	1.04E-09	1.43E-09	2.29E-09	5.23E-09	4.53E-06	FGR-13 Morbidity [a]
14274-82-9	Th-228+D	1.91E+00	S	5.00E-04	3.00E-10	4.22E-10	8.09E-10	1.43E-07	7.76E-06	FGR-13 Morbidity [a]
14269-63-7	Th-230	7.70E+04	S	5.00E-04	9.10E-11	1.19E-10	2.02E-10	2.85E-08	8.19E-10	FGR-13 Morbidity [a]
7440-29-1	Th-232	1.41E+10	S	5.00E-04	1.01E-10	1.33E-10	2.31E-10	4.33E-08	3.42E-10	FGR-13 Morbidity [a]
13966-29-5	U-234	2.45E+05	M	2.00E-02	7.07E-11	9.55E-11	1.58E-10	1.14E-08	2.52E-10	FGR-13 Morbidity [a]
15117-96-1	U-235+D	7.04E+08	M	2.00E-02	7.18E-11	9.76E-11	1.63E-10	1.01E-08	5.43E-07	FGR-13 Morbidity [a]
7440-61-1	U-238	4.47E+09	M	2.00E-02	6.40E-11	8.66E-11	1.43E-10	9.32E-09	4.99E-11	FGR-13 Morbidity [a]
7440-61-1	U-238+D	4.47E+09	M	2.00E-02	8.71E-11	1.21E-10	2.10E-10	9.35E-09	1.14E-07	FGR-13 Morbidity [a]

[a] USEPA 1999b.

Table K-10A. Toxicity Criteria for Metal Contaminants of Potential Concern: Carcinogenic Effects

COPC:	Arsenic	Cadmium [a]	Lead [b]
CAS Number:	7440-38-2	7440-43-9	7439-92-1
Weight of Evidence Classification [c]	A	B1	B2
Oral Exposure Route			
SF_o, $(mg/kg/day)^{-1}$	1.5E+00	NA	NA
Type of Cancer	Organ (liver, kidney, lung, and bladder); Skin	NA	Kidneys (renal tumors); genetic expression
SF_o Basis	Drinking Water	NA	Dietary/subcutaneous exposures to rats/mice
SF_o Source	USEPA (2011b)	USEPA (2011b)	USEPA (2011b)
Dermal Exposure Route			
SF_d, $(mg/kg/day)^{-1}$ [d]	1.6E+00	NA	NA
ABS, unitless [e]	0.03	0.001	NA
GIABS, % [e]	95	0.025	100
SF_d Source	Calculated from SF_o	NA	NA
Inhalation Exposure Route			
IUR, $(\mu g/m^3)^{-1}$	4.3E-03	1.8E-03	NA
Type of Cancer	Lung	Lung, trachea, bronchial	NA
IUR Basis	Inhalation	Inhalation & injection studies on rats and mice	NA
IUR Source	USEPA (2011b)	USEPA (2011b)	USEPA (2011b)

[a] The SF_o, ABS, and GIABS values for cadmium are based on diet.

[b] No toxicity criteria are established for determining risk due to lead exposures.

[c] Weight of Evidence (WOE) Classifications:

A - Human carcinogen

B1 - Probable human carcinogen - based on limited evidence of carcinogenicity in humans

B2 - Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals

[d] Calculated using the following equation: $SF_d = SF_o \div GIABS$ (%).

[e] ABS (dermal absorption fraction from soil) and GIABS (gastrointestinal absorption efficiencies) obtained from RAGS Part E (USEPA 2004) and USEPA's (2011a) most recent Regional Screening Levels Table. Default GIABS value of 100% is assumed for COPCs that lack available published data (USEPA 2004).

IUR - Inhalation unit risk.

SF_d - Dermal cancer slope factor.

SF_o - Oral cancer slope factor.

NA - No published oral slope factor is available.

Table K-10B. Toxicity Criteria for Metal Contaminants of Potential Concern: Non-Carcinogenic Effects

COPC:	Arsenic	Cadmium [a]	Lead [b]
CAS Number:	7440-38-2	7440-43-9	7439-92-1
Oral Exposure Route			
RfD_o, mg/kg/day	3.0E-04	1.0E-03	[c]
RfDo Basis	Human chronic oral studies	Human studies	[c]
Critical Effect(s)	Skin/hyperpigmentation, keratosis: Cardiovascular/possible vascular complications, congestive heart failure	Kidney/Significant proteinuria	Anemia, hypertension, developmental effects
Confidence Level	Medium	High	[c]
Uncertainty Factor, unitless	3	10	[c]
RfD_o Source	USEPA (2011b)	USEPA (2011b)	ATSDR (2007)
Dermal Exposure Route			
RfD_d, mg/kg/day [d]	2.9E-04	[c]	[c]
ABS, unitless [e]	0.03	0.001	[c]
GIABS, % [e]	95	0.025	100
RfD_d Source	Calculated from RfD_o	[c]	[c]
Inhalation Exposure Route			
RfC, mg/m^3	1.5E-05	1.0E-05	[c]
RfC Basis	[c]	[c]	[c]
Critical Effect(s)	Development effects, cardiovascular system, nervous system	Respiratory/pulmonary effects	Anemia, hypertension, developmental effects
Confidence Level	[c]	[c]	[c]
Uncertainty Factor, unitless	[c]	[c]	[c]
RfC Source	CalEPA (2011)	USEPA (2011a)	ATSDR (2007)

Table K-10B. Toxicity Criteria for Metal Contaminants of Potential Concern: Non-Carcinogenic Effects

COPC:	Arsenic	Cadmium [a]	Lead [b]
Target Organs			
Blood Chemistry/Erythrocytes			X
Cardiovascular System	X		X
Central Nervous System/Neurotoxicity	X		
Fetus (Development)	X		X
Kidneys		X [f]	
Pulmonary/Respiratory System		X [f]	
Skin	X		

[a] The RfD_o, ABS, and GIABS values for cadmium are based on diet.

[b] No toxicity criteria are established for determining risk due to lead exposures.

[c] Information is currently not available.

[d] Calculated using the following equation: Dermal RfD = Oral RfD x GIABS (%).

[e] ABS (dermal absorption fraction from soil) and GIABS (gastrointestinal absorption efficiencies) obtained from RAGS Part E (USEPA 2004) and USEPA's (2011a) most recent Regional Screening Levels Table. Default GIABS value of 100% is assumed for COPCs that lack available published data (USEPA, 2004).

[f] Target organs are applicable to cadmium exposures via diet and water ingestion.

RfC - Inhalation reference concentration.

SF_d - Dermal cancer slope factor.

SF_o - Oral cancer slope factor.

X - Indicates target organ/organ system for COPC.

Table K-10C. Summary of Target Organs and Critical Effects for Non-Carcinogenic Exposures to Metal Contaminants of Potential Concern

CAS No.	COPC	Target Organ/Critical Effect [a]						
		Blood Chemistry/ Erythrocytes	Cardiovascular	Central Nervous System/ Neurotoxicity	Developmental (Including Fetal) Effects	Kidneys	Pulmonary/ Respiratory System	Skin
7440-38-2	Arsenic		X	X	X			X
7440-43-9	Cadmium (Diet)					X	X	
7440-43-9	Cadmium (Water)					X	X	
7439-92-1	Lead	X	X		X			

[a] Sources for target organs/critical effects are the same as those cited in Table K-13B.

Table K-11A. Receptor-Specific Radiological Dose and Risk Characterization for SLDS Background Soil, Sewer Line Sediment and Soil Adjacent to Sewer Lines

Receptor	ISOU Medium [a]	Total Dose/Risk	
		Max. Dose (mrem/yr)	Max. CR (unitless)
Current Industrial Worker	Inaccessible Soil (Ground Cover Present)	0.4	8.1E-06
	Accessible Soil (Ground Cover Absent)	10	1.8E-04
	Property-Wide [b]	5.2	9.4E-05
Future Industrial Worker	Inaccessible Soil (Ground Cover Absent)	10	1.8E-04
	Accessible Soil (Ground Cover Absent)	10	1.8E-04
	Property-Wide [b]	10.1	1.8E-04
Current/Future Recreational User	Inaccessible (Levee Present as Ground Cover)	0	8.1E-11
	Accessible Soil (Ground Cover Absent)	0.4	2.9E-06
	Property-Wide [b]	0.2	1.5E-06
Current/Future Construction Worker	Inaccessible Soil (Ground Cover Absent) [b]	5	3.4E-06
Current/Future Utility Worker	Inaccessible Soil (Ground Cover Absent) [b]	0.6	3.7E-07
Current/Future Sewer Maintenance Worker	Sediment Inside Sewer Lines [c]	0.01	9.2E-09
Current/Future Utility Worker	Soil Adjacent to Sewer Lines [c]	0.3	2.6E-07

[a] SLDS background soil risks were calculated using the soil background value (BV) as the EPC, which is presented in Table 4-1. The soil BV was calculated from SLDS background data presented by USACE (1999a). SLDS background soil risks are being compared to those estimated for inaccessible soil and soil adjacent to sewer line receptor scenarios. Background sewer sediment risks were calculated using the SLDS sediment BV as the EPC, which is presentd in Table 4-1. The background sediment data collected during the ISOU RI were used to calculate the BV (see Appendix I). The SLDS background sediment risks are being compared to those estimated for sewer sediment receptor scenarios.

[b] The RESRAD default value of 10,000 m^2 was applied as the assumed area of contamination each for inaccessible soil and accessible soil areas for all receptor scenarios. Property-wide background dose and risk calculations for soil assume a total area of 20,000 m^2 for combined inaccessible and accessible soil areas for the industrial worker and recreational user scenarios, with 50 percent of the total background area assumed to be inaccessible soil and 50 percent of the total background area assumed to be accessible soil.

[c] The area of contamination assumed for background sewer sediment and background soil adjacent to sewers is 180 m^2.

Table K-11B. Receptor-Specific Metals Risk Characterization for SLDS Background Soil, Sewer Line Sediment and Soil Adjacent to Sewer Lines

Receptor [a]	**ISOU Medium** [b]	**Carcinogenic Risk**		**Noncarcinogenic Risk**	
		Total Background CR	**Risk Driver COPC**	**Total Background HI**	**Risk Driver COPC**
Future Industrial Worker	Inaccessible Soil (Ground Cover Absent)	1.9E-06	Arsenic	0.012	Arsenic
	Accessible Soil (Ground Cover Absent)	1.9E-06	Arsenic	0.012	Arsenic
	Property-Wide [c]	1.9E-06	Arsenic	0.012	Arsenic
Current/Future Construction Worker	Inaccessible Soil (Ground Cover Absent) [d]	4.0E-07	Arsenic	0.063	Arsenic
Current/Future Utility Worker	Inaccessible Soil (Ground Cover Absent) [d]	4.5E-08	Arsenic	0.0070	Arsenic
Current/Future Sewer Maintenance Worker	Sediment Inside Sewer Lines [d]	4.7E-07	Arsenic	0.0029	Arsenic
Current/Future Utility Worker	Soil Adjacent to Sewer Lines [d]	4.5E-08	Arsenic	0.0072	Arsenic

[a] Background risks are not presented for the current industrial worker and current/future recreational user scenarios because of the determinations of no complete exposure pathways and no metal COPCs, respectively.

[b] SLDS background soil risks were calculated using the soil background value (BV) as the EPC, which is presented in Table 4-1. The soil BV was calculated from SLDS background data presented by USACE (1999a). SLDS background soil risks are being compared to those estimated for inaccessible soil and soil adjacent to sewer line receptor scenarios. Background sewer sediment risks were calculated using the SLDS sediment BV as the EPC, which is presentd in Table 4-1. The background sediment data collected during the ISOU RI were used to calculate the BV (see Appendix I). The SLDS background sediment risks are being compared to those estimated for sewer sediment receptor scenarios.

[c] For metals risk calculations, unlike radiological dose and risk calculations, assumptions regarding the area of contamination are not necessary, but can be used in the calculation of the property-wide, area-weighted average risk for exposures to combined inaccessible and accessible soils. Therefore, for consistency with the radiological dose and risk calculations, 10,000 m^2 was applied as the assumed area of contamination each for inaccessible soil and accessible soil areas for all receptor scenarios. Property-wide background risk calculations for soil assume a total area of 20,000 m^2 for combined inaccessible and accessible soil areas for the future industrial worker scenario, with 50 percent of the total background area assumed to be inaccessible soil and 50 percent of the total background area assumed to be accessible soil.

[d] Assumptions regarding the area of contamination for background inaccessible soil for current/future construction and utility workers, background sewer sediment for current/future maintenance workers, and background soil adjacent to sewers for current/future utility workers are not applicable to risk calculations for metals.

NA - Calculation of a total background CR or HI and determination of risk driver COPCs is not applicable for the scenario due to incomplete exposure pathways (current industrial worker) or no metals data were collected (current/future recreational user).

Table K-12. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Current Industrial Worker

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
Background [b]	Inaccessible [c]	10,000	NA	0.4	8.1E-06
	Accessible [d]	10,000	NA	10	1.8E-04
	Area-Wide [e]	20,000	NA	5.2	9.4E-05
SLDS (Sitewide)	Inaccessible [c]	381,357	1.1E-05	0.2	3.1E-06
	Accessible [d]	776,844	1.7E-04	<BKGD	<BKGD
	Sitewide [e]	1,158,201	1.1E-04	1.3	2.1E-05
Mallinckrodt Properties					
Plant 1	Inaccessible [c]	10,500	2.8E-05	1.0	2.0E-05
	Accessible [d]	11,700	1.9E-04	0.3	8.9E-06
	Property-Wide [e]	22,200	1.1E-04	1.1	1.9E-05
Plant 2	Inaccessible [c]	3,563	8.7E-06	0.03	5.6E-07
	Accessible [d]	16,531	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	20,094	1.4E-04	3.0	5.1E-05
Plant 6	Inaccessible [c]	2,370	1.5E-05	0.4	7.4E-06
	Accessible [d]	29,965	1.9E-04	0.5	7.7E-06
	Property-Wide [e]	32,335	1.8E-04	4.8	8.1E-05
Mallinckrodt Security Gate 49	Inaccessible [c]	5	6.4E-06	<BKGD	<BKGD
	Accessible [d]	435	1.5E-04	<BKGD	<BKGD
	Property-Wide [e]	440	1.5E-04	3.2	5.8E-05
Industrial/Commercial Vicinity Properties					
DT-2	Inaccessible [f]	12,665	6.1E-09	<BKGD	<BKGD
	Accessible [d]	77,475	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	90,140	1.5E-04	3.1	5.4E-05
DT-4 North	Inaccessible [c]	7,962	5.2E-05	2.3	4.4E-05
	Accessible [d]	6,178	1.8E-04	0.2	3.4E-06
	Property-Wide [e]	14,140	1.1E-04	0.9	1.5E-05
DT-6	Inaccessible [c]	3,582	2.3E-05	0.8	1.5E-05
	Accessible [d]	6,686	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	10,268	1.2E-04	1.6	2.5E-05
DT-8	Inaccessible [c]	20,471	6.7E-06	<BKGD	<BKGD
	Accessible [d]	85,560	1.8E-04	<BKGD	0.0E+00
	Property-Wide [e]	106,031	1.5E-04	3.0	5.3E-05

Table K-12. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Current Industrial Worker

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
DT-10	Inaccessible [c]	726	9.7E-06	0.1	1.6E-06
	Accessible [d]	10,479	1.8E-04	3.3	<BKGD
	Property-Wide [e]	11,205	1.7E-04	7.6	7.5E-05
DT-15	Inaccessible [f]	5,505	5.4E-09	<BKGD	<BKGD
	Accessible [d]	3,754	1.1E-04	<BKGD	<BKGD
	Property-Wide [e]	9,259	4.4E-05	<BKGD	<BKGD
DT-29	Inaccessible [c]	533	5.7E-06	<BKGD	<BKGD
	Accessible [d]	1,345	1.8E-04	0.7	3.3E-06
	Property-Wide [e]	1,878	1.3E-04	2.8	3.9E-05
DT-34	Inaccessible [c]	4,780	9.0E-06	0.05	8.7E-07
	Accessible [d]	9,846	1.2E-04	<BKGD	<BKGD
	Property-Wide [e]	14,626	8.0E-05	<BKGD	<BKGD
South of Angelrodt Property Group	Inaccessible [c]	6,508	7.4E-06	<BKGD	<BKGD
	Accessible [d]	34,159	1.5E-04	<BKGD	<BKGD
	Combined Properties [e]	40,667	1.3E-04	1.9	3.3E-05
West of Broadway Property Group	Inaccessible [c]	33,043	6.4E-06	<BKGD	<BKGD
	Accessible [d]	50,847	1.5E-04	<BKGD	<BKGD
	Combined Properties [e]	83,890	9.3E-05	0.1	<BKGD
Railroad Vicinity Properties					
DT-3	Inaccessible [c]	6,363	9.5E-06	0.08	1.4E-06
	Accessible [d]	13,562	1.8E-04	0.01	<BKGD
	Property-Wide [e]	19,925	1.3E-04	2.0	3.1E-05
DT-9 Levee	Inaccessible [f]	84,920	4.7E-09	<BKGD	<BKGD
	Accessible [d]	188,158	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	273,078	1.1E-04	1.3	2.1E-05
DT-9 Main Tracks	Inaccessible [c]	36,630	9.8E-06	0.09	1.7E-06
	Accessible [d]	16,803	1.5E-04	<BKGD	<BKGD
	Property-Wide [e]	53,433	5.3E-05	<BKGD	<BKGD
DT-9 Rail Yard	Inaccessible [c]	24,384	2.0E-05	0.64	1.2E-05
	Accessible [d]	131,791	1.9E-04	0.2	6.4E-06
	Property-Wide [e]	156,175	1.6E-04	3.8	6.6E-05
Terminal RR Soil Spoils Area	Inaccessible [c]	10,636	2.5E-05	0.85	1.6E-05
	Accessible [d]	68,230	1.6E-04	<BKGD	<BKGD
	Property-Wide [e]	78,866	1.5E-04	2.9	5.1E-05

Table K-12. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Current Industrial Worker

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
DT-12	Inaccessible [c]	23,009	7.3E-06	<BKGD	<BKGD
	Accessible [d]	13,730	1.6E-04	<BKGD	<BKGD
	Property-Wide [e]	36,739	6.6E-05	<BKGD	<BKGD
Roadways					
Angelrodt Street	Inaccessible [c]	NA	7.9E-06	<BKGD	<BKGD
Bremen Avenue	Inaccessible [c]	NA	1.1E-05	0.17	3.2E-06
Buchanan Street	Inaccessible [c]	NA	1.2E-05	0.19	3.6E-06
Destrehan Street	Inaccessible [c]	NA	1.3E-05	0.28	5.3E-06
Hall Street	Inaccessible [c]	NA	1.1E-05	0.14	2.7E-06
Mallinckrodt Street	Inaccessible [c]	NA	7.8E-06	<BKGD	<BKGD
North Second Street	Inaccessible [c]	NA	9.3E-06	0.07	1.2E-06
Salisbury Street	Inaccessible [c]	NA	5.4E-06	<BKGD	<BKGD

[a] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

[b] The RESRAD default value of 10,000 m^2 was applied as the assumed area each for inaccessible soil and accessible soil areas for all receptor scenarios. Property-wide background dose and risk calculations for soil assume a total area of 20,000 m^2 for combined inaccessible and accessible soil areas for the industrial worker and recreational user scenarios, with 50 percent of the total background area assumed to be inaccessible soil and 50 percent of the total background area assumed to be accessible soil.

[c] Inaccessible soil dose and risk calculations for all properties under the current scenario, except for the levee properties (DT-2, DT-9 Levee, and DT-15), assume a 1-foot thick soil cover is in place. Roadway areas are all considered to be inaccessible soil areas.

[d] Accessible soil dose and risk were calculated under the assumption of no ground cover.

[e] Property-wide dose and risk are calculated as weighted averages of inaccessible and accessible soil dose and risk.

[f] Inaccessible soil dose and risk for levee properties (DT-2, DT-9 Levee, and DT-15) were calculated by assuming a 1-meter thick soil cover is in place, and this assumption remains the same for both current and future scenarios, as the levee will remain in place.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table K-13A. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Future Industrial Worker

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
Background [b]	Inaccessible [c]	10,000	NA	10	1.8E-04
	Accessible [d]	10,000	NA	10	1.8E-04
	Area-Wide [e]	20,000	NA	10	1.8E-04
SLDS (Sitewide)	Inaccessible [c]	381,357	2.2E-04	2.5	4.3E-05
	Accessible [d]	776,844	1.7E-04	<BKGD	<BKGD
	Sitewide [e]	1,158,201	1.8E-04	0.2	4.4E-06
Mallinckrodt Properties					
Plant 1	Inaccessible [c]	10,500	7.0E-04	29	5.2E-04
	Accessible [d]	11,700	1.9E-04	0.3	8.9E-06
	Property-Wide [e]	22,200	4.3E-04	14	2.5E-04
Plant 2	Inaccessible [c]	3,563	1.7E-04	<BKGD	<BKGD
	Accessible [d]	16,531	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	20,094	1.7E-04	<BKGD	<BKGD
Plant 6	Inaccessible [c]	2,370	4.8E-04	18	3.0E-04
	Accessible [d]	29,965	1.9E-04	0.5	7.7E-06
	Property-Wide [e]	32,335	2.1E-04	1.7	2.9E-05
Mallinckrodt Security Gate 49	Inaccessible [c]	5	8.4E-05	<BKGD	<BKGD
	Accessible [d]	435	1.5E-04	<BKGD	<BKGD
	Property-Wide [e]	440	1.5E-04	<BKGD	<BKGD
Industrial/Commercial Vicinity Properties					
DT-2	Inaccessible [f]	12,665	6.1E-09	<BKGD	<BKGD
	Accessible [d]	77,475	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	90,140	1.5E-04	<BKGD	<BKGD
DT-4 North	Inaccessible [c]	7,962	9.7E-04	45	7.9E-04
	Accessible [d]	6,178	1.8E-04	0.2	3.4E-06
	Property-Wide [e]	14,140	6.2E-04	25	4.4E-04
DT-6	Inaccessible [c]	3,582	4.3E-04	15	2.5E-04
	Accessible [d]	6,686	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	10,268	2.6E-04	4.8	7.9E-05
DT-8	Inaccessible [c]	20,471	1.5E-04	<BKGD	<BKGD
	Accessible [d]	85,560	1.8E-04	<BKGD	0.0E+00
	Property-Wide [e]	106,031	1.7E-04	<BKGD	<BKGD
DT-10	Inaccessible [c]	726	2.1E-04	1.3	3.2E-05
	Accessible [d]	10,479	1.8E-04	3.3	<BKGD
	Property-Wide [e]	11,205	1.8E-04	3.2	2.0E-06

Table K-13A. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Future Industrial Worker

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
DT-15	Inaccessible [f]	5,505	5.4E-09	<BKGD	<BKGD
	Accessible [d]	3,754	1.1E-04	<BKGD	<BKGD
	Property-Wide [e]	9,259	4.4E-05	<BKGD	<BKGD
DT-29	Inaccessible [c]	533	9.4E-05	<BKGD	<BKGD
	Accessible [d]	1,345	1.8E-04	0.7	3.3E-06
	Property-Wide [e]	1,878	1.6E-04	<BKGD	<BKGD
DT-34	Inaccessible [c]	4,780	1.7E-04	<BKGD	<BKGD
	Accessible [d]	9,846	1.2E-04	<BKGD	<BKGD
	Property-Wide [e]	14,626	1.3E-04	<BKGD	<BKGD
South of Angelrodt Property Group	Inaccessible [c]	6,508	1.6E-04	<BKGD	<BKGD
	Accessible [d]	34,159	1.5E-04	<BKGD	<BKGD
	Combined Properties [e]	40,667	1.5E-04	<BKGD	<BKGD
West of Broadway Property Group	Inaccessible [c]	33,043	1.3E-04	<BKGD	<BKGD
	Accessible [d]	50,847	1.5E-04	<BKGD	<BKGD
	Combined Properties [e]	83,890	1.4E-04	<BKGD	<BKGD
Railroad Vicinity Properties					
DT-3	Inaccessible [c]	6,363	1.9E-04	0.1	9.0E-06
	Accessible [d]	13,562	1.8E-04	0.01	<BKGD
	Property-Wide [e]	19,925	1.8E-04	0.04	2.8E-06
DT-9 Levee	Inaccessible [f]	84,920	4.7E-09	<BKGD	<BKGD
	Accessible [d]	188,158	1.7E-04	<BKGD	<BKGD
	Property-Wide [e]	273,078	1.1E-04	<BKGD	<BKGD
DT-9 Main Tracks	Inaccessible [c]	36,630	1.9E-04	<BKGD	6.0E-06
	Accessible [d]	16,803	1.5E-04	<BKGD	<BKGD
	Property-Wide [e]	53,433	1.7E-04	<BKGD	<BKGD
DT-9 Rail Yard	Inaccessible [c]	24,384	4.9E-04	17	3.1E-04
	Accessible [d]	131,791	1.9E-04	0.2	6.4E-06
	Property-Wide [e]	156,175	2.3E-04	2.8	5.4E-05
Terminal RR Soil Spoils Area	Inaccessible [c]	10,636	4.4E-04	14	2.6E-04
	Accessible [d]	68,230	1.6E-04	<BKGD	<BKGD
	Property-Wide [e]	78,866	2.0E-04	0.9	2.2E-05
DT-12	Inaccessible [c]	23,009	1.3E-04	<BKGD	<BKGD
	Accessible [d]	13,730	1.6E-04	<BKGD	<BKGD
	Property-Wide [e]	36,739	1.4E-04	<BKGD	<BKGD

Table K-13A. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil: Future Industrial Worker

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
Roadways					
Angelrodt Street	Inaccessible [c]	NA	1.7E-04	<BKGD	<BKGD
Bremen Avenue	Inaccessible [c]	NA	2.2E-04	2.9	4.2E-05
Buchanan Street	Inaccessible [c]	NA	2.3E-04	3.3	4.8E-05
Destrehan Street	Inaccessible [c]	NA	2.3E-04	2.1	4.7E-05
Hall Street	Inaccessible [c]	NA	2.3E-04	2.9	5.5E-05
Mallinckrodt Street	Inaccessible [c]	NA	1.3E-04	<BKGD	<BKGD
North Second Street	Inaccessible [c]	NA	1.8E-04	<BKGD	<BKGD
Salisbury Street	Inaccessible [c]	NA	1.0E-04	<BKGD	<BKGD

[a] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

[b] The RESRAD default value of 10,000 m^2 was applied as the assumed area each for inaccessible soil and accessible soil areas for all receptor scenarios. Property-wide background dose and risk calculations for soil assume a total area of 20,000 m^2 for combined inaccessible and accessible soil areas for the industrial worker and recreational user scenarios, with 50 percent of the total background area assumed to be inaccessible soil and 50 percent of the total background area assumed to be accessible soil.

[c] Inaccessible soil dose and risk calculations for all properties under the future scenario, except for the levee properties (DT-2, DT-9 Levee, and DT-15), assume no ground cover. Roadway areas are all considered to be inaccessible soil areas.

[d] Accessible soil dose and risk were calculated under the assumption of no ground cover.

[e] Property-wide dose and risk are calculated as weighted averages of inaccessible and accessible soil dose and risk.

[f] Inaccessible soil dose and risk for levee properties (DT-2, DT-9 Levee, and DT-15) were calculated by assuming a 1-meter thick soil cover is in place, and this assumption remains the same for both current and future scenarios, as the levee will remain in place.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table K-13B. Sitewide and Property-Specific Metals Risk Characterization for Inaccessible Soil and Accessible Soil within the Former Uranium-Ore Processing Area: Future Industrial Worker

Property	Soil Operable Unit	Area (m^2)	Total Property CR [a]	Total Property HI [a]
Background	Inaccessible [b]	--	1.9E-06	0.012
	Accessible [b]	--	1.9E-06	0.012
	Area-Wide [c]	--	1.9E-06	0.012
SLDS (Sitewide)	Inaccessible [b]	381,357	1.7E-05	0.10
	Accessible [b]	776,844	2.6E-06	0.017
	Sitewide [c]	1,158,201	7.2E-06	0.045
Plant 2	Inaccessible [b]	3,563	1.5E-06	0.0094
	Accessible [b]	16,531	2.9E-06	0.020
	Property-Wide [c]	20,094	2.7E-06	0.018
Plant 6	Inaccessible [b]	2,370	1.7E-06	0.011
	Accessible [b]	29,965	2.7E-06	0.017
	Property-Wide [c]	32,335	2.6E-06	0.017
DT-10	Inaccessible [b]	20,471	2.9E-05	0.18
	Accessible [b]	85,560	8.3E-06	0.052
	Property-Wide [c]	106,031	1.2E-05	0.076
DT-9 Main Tracks	Inaccessible [b]	36,630	1.4E-06	0.0090
DT-12	Inaccessible [b]	23,009	2.9E-05	0.18
Hall Street	Inaccessible [b]	NA	1.7E-06	0.011
Mallinckrodt Street	Inaccessible [b]	NA	2.6E-06	0.016
Destrehan Street	Inaccessible [b]	NA	3.0E-06	0.019

[a] Incidental ingestion of arsenic was the predominant contributor to all total CRs and HIs.

[b] Inaccessible soil CR and HI calculations for all properties under the future scenario assume no ground cover. Roadway areas are all considered to be inaccessible soil areas.

[c] Property-wide CRs and HIs are calculated as weighted averages of inaccessible and accessible soil CRs and HIs.

Gray shading indicates that the CR or HI exceeds the corresponding background CR or HI. The non-shaded CRs and HIs are within the range of background.

Table K-14. Combined and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil and Accessible Soil within Properties Encompassing the St. Louis Riverfront Trail (DT-2, DT-9 Levee, and DT-15): Current/Future Recreational User

Property	Soil Operable Unit	Area (m^2)	Risk with Background	Dose & Risk Above Background [a]	
			Max. CR (unitless)	Dose (mrem/yr)	Max. CR (unitless)
Background [b]	Inaccessible [c]	10,000	NA	0	8.1E-11
	Accessible [d]	10,000	NA	0.4	2.9E-06
	Area-Wide [e]	20,000	NA	0.2	1.5E-06
Industrial/Commercial Vicinity Properties					
Combined Properties with St. Louis Riverfront Trail (DT-2, DT-9 Levee, and DT-15)	Inaccessible [c]	103,089	7.3E-11	0.00001	< BKGD
	Accessible [d]	269,387	2.7E-06	0.02	< BKGD
	Combined Properties [e]	372,476	1.9E-06	0.10	4.3E-07
DT-2	Inaccessible [c]	12,665	7.7E-11	0.00001	< BKGD
	Accessible [d]	77,475	2.8E-06	0.04	< BKGD
	Property-Wide [e]	90,140	2.4E-06	0.2	9.0E-07
DT-9 Levee	Inaccessible [c]	84,920	6.9E-11	0.00001	< BKGD
	Accessible [d]	188,158	2.7E-06	0.02	< BKGD
	Property-Wide [e]	273,078	1.9E-06	0.09	3.9E-07
DT-15	Inaccessible [c]	5,505	7.5E-11	0.00001	< BKGD
	Accessible [d]	3,754	1.8E-06	<BKGD	< BKGD
	Property-Wide [e]	9,259	7.2E-07	<BKGD	< BKGD

[a] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

[b] The RESRAD default value of 10,000 m^2 was applied as the assumed area each for inaccessible soil and accessible soil areas for all receptor scenarios. Property-wide background dose and risk calculations for soil assume a total area of 20,000 m^2 for combined inaccessible and accessible soil areas for the industrial worker and recreational user scenarios, with 50 percent of the total background area assumed to be inaccessible soil and 50 percent of the total background area assumed to be accessible soil.

[c] Inaccessible soil dose and risk calculations for levee properties (DT-2, DT-9 Levee, and DT-15) under the combined current/future scenario conservatively assume a minimal soil cover thickness of 1 meter for the levee.

[d] Accessible soil dose and risk were calculated under the assumption of no ground cover.

[e] Property-wide dose and risk are calculated as weighted averages of inaccessible and accessible soil dose and risk.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table K-15A. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil: Current/Future Construction Worker

Property	Risk with Background [a,b]	Dose & Risk Above Background [b]	
	Max. CR (unitless)	Max. Dose (mrem/yr)	Max. CR (unitless)
Background	NA	5.1	3.4E-06
SLDS (Sitewide)	4.2E-06	0.9	8.0E-07
Mallinckrodt Properties			
Plant 1	1.3E-05	15	9.6E-06
Plant 2	3.2E-06	<BKGD	<BKGD
Plant 6	9.7E-06	9.9	6.3E-06
Mallinckrodt Security Gate 49	1.5E-06	<BKGD	<BKGD
Industrial/Commercial Vicinity Properties			
DT-2	4.2E-06	0.9	8.0E-07
DT-4 North	1.8E-05	23	1.5E-05
DT-6	8.0E-06	7.9	4.6E-06
DT-8	2.8E-06	<BKGD	<BKGD
DT-10	4.0E-06	0.9	6.0E-07
DT-15	2.7E-06	<BKGD	<BKGD
DT-29	1.7E-06	<BKGD	<BKGD
DT-34	3.1E-06	<BKGD	<BKGD
South of Angelrodt Property Group	3.0E-06	<BKGD	<BKGD
West of Broadway Property Group	2.5E-06	<BKGD	<BKGD
Railroad Vicinity Properties			
DT-3	3.6E-06	<BKGD	2.0E-07
DT-9 Levee	2.1E-06	<BKGD	<BKGD
DT-9 Rail Yard	9.3E-06	7.9	5.9E-06
DT-9 Main Line	3.5E-06	<BKGD	1.0E-07
Terminal RR Soil Spoils Area	8.3E-06	6.9	4.9E-06
DT-12	2.5E-06	<BKGD	<BKGD
Roadways			
Angelrodt Street	3.2E-06	<BKGD	<BKGD
Bremen Avenue	4.3E-06	1.9	9.0E-07
Buchanan Street	4.4E-06	1.9	1.0E-06
Destrehan Street	4.2E-06	0.9	8.0E-07
Hall Street	4.4E-06	1.9	1.0E-06
Mallinckrodt Street	2.5E-06	<BKGD	<BKGD
North Second Street	3.3E-06	<BKGD	<BKGD
Salisbury Street	1.9E-06	<BKGD	<BKGD

[a] Dose and risk calculations for all properties assume no ground cover for the construction worker.

[b] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table K-15B. Sitewide and Property-Specific Metals Risk Characterization for Inaccessible Soil within the Former Uranium-Ore Processing Area: Current/Future Construction Worker

Property	Total Property CR [a]	Total Property HI [a]
Background	4.0E-07	0.063
SLDS (Sitewide)	3.6E-06	0.56
Plant 2	3.2E-07	0.050
Plant 6	3.6E-07	0.057
DT-10	6.2E-06	0.96
DT-9 Main Tracks	3.1E-07	0.048
DT-12	6.3E-06	0.99
Hall Street	3.7E-07	0.058
Mallinckrodt Street	5.6E-07	0.088
Destrehan Street	6.5E-07	0.10

[a] CR and HI calculations for all properties assume no ground cover. Incidental ingestion of arsenic was the predominant contributor to all total CRs and HIs.

Gray shading indicates that the CR or HI exceeds the corresponding background CR or HI. The non-shaded CRs and HIs are within the range of background.

Table K-16A. Sitewide and Property-Specific Radiological Dose and Risk Characterization for Inaccessible Soil: Current/Future Utility Worker

Property	Risk with Background [a,b]	Dose & Risk Above Background [b]	
	Max. CR (unitless)	Max. Dose (mrem/yr)	Max. CR (unitless)
Background	NA	0.6	3.7E-07
SLDS (Sitewide)	4.6E-07	0.4	9.0E-08
Mallinckrodt Properties			
Plant 1	1.5E-06	1.4	1.1E-06
Plant 2	3.5E-07	0.4	<BKGD
Plant 6	1.0E-06	1.4	6.3E-07
Mallinckrodt Security Gate 49	1.7E-07	<BKGD	<BKGD
Industrial/Commercial Vicinity Properties			
DT-2	4.7E-07	0.4	1.0E-07
DT-4 North	2.0E-06	2.4	1.6E-06
DT-6	8.9E-07	0.4	5.2E-07
DT-8	3.1E-07	<BKGD	<BKGD
DT-10	4.4E-07	0.4	7.0E-08
DT-15	3.0E-07	<BKGD	<BKGD
DT-29	1.9E-07	<BKGD	<BKGD
DT-34	3.4E-07	<BKGD	<BKGD
South of Angelrodt Property Group	3.3E-07	<BKGD	<BKGD
West of Broadway Property Group	2.8E-07	<BKGD	<BKGD
Railroad Vicinity Properties			
DT-3	4.0E-07	0.4	3.0E-08
DT-9 Levee	2.4E-07	<BKGD	<BKGD
DT-9 Rail Yard	1.0E-06	0.4	6.3E-07
DT-9 Main Line	3.8E-07	0.4	1.0E-08
Terminal RR Soil Spoils Area	9.3E-07	0.4	5.6E-07
DT-12	2.7E-07	<BKGD	<BKGD
Roadways			
Angelrodt Street	3.5E-07	0.4	<BKGD
Bremen Avenue	4.5E-07	0.4	8.0E-08
Buchanan Street	4.8E-07	0.4	1.1E-07
Destrehan Street	4.7E-07	0.4	1.0E-07
Hall Street	4.9E-07	0.4	1.2E-07
Mallinckrodt Street	2.8E-07	<BKGD	<BKGD
Salisbury	2.1E-07	<BKGD	<BKGD
North Second Street	3.7E-07	0.4	0.0E+00

[a] Dose and risk calculations for all properties assume no ground cover for the utility worker.

[b] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table K-16B. Sitewide and Property-Specific Metals Risk Characterization for Inaccessible Soil within the Former Uranium-Ore Processing Area: Current/Future Utility Worker

Property	Total Property CR [a]	Total Property HI [a]
Background	4.5E-08	0.0070
SLDS (Sitewide)	4.0E-07	0.062
Plant 2	3.6E-08	0.0056
Plant 6	4.0E-08	0.0063
DT-10	6.9E-07	0.11
DT-9 Main Tracks	3.5E-08	0.0054
DT-12	7.1E-07	0.11
Hall Street	4.1E-08	0.0064
Mallinckrodt Street	6.3E-08	0.010
Destrehan Street	7.2E-08	0.011

[a] CR and HI calculations for all properties assume no ground cover. Incidental ingestion of arsenic was the predominant contributor to all total CRs and HIs.

Gray shading indicates that the CR or HI exceeds the corresponding background CR or HI. The non-shaded CRs and HIs are within the range of background.

Table K-17. Radiological Dose and Risk Characterization for Interior Building Surfaces: Industrial Worker

Property	Building	Dose (mrem/year)	CR
Plant 1	Building 7	0.4	1.2E-06
Plant 1	Building 26	0.4	1.3E-06
Plant 2	Building 41	0.4	1.2E-06
Plant 2	Building 508	0.3	1.1E-06
DT-6	Storage Building	0.2	6.2E-07
DT-10	Metal Storage Building	0.3	1.0E-06
DT-10	Wood Storage Building	0.2	5.0E-07

Table K-18. Radiological Dose and Risk Characterization for Exterior Building Surfaces: MaintenanceWorker

Property	Building	Dose (mrem/year)	CR
Plant 1	Building 25	0.1	3.2E-07
Plant 1	Building X	<0.1	1.2E-07
DT-10	Wood Storage Building	0.3	1.2E-06
DT-14	Horizontal Beam between L-Shaped Building & Brick Warehouse	<0.1	1.6E-07

Table K-19A. Sitewide and Location-Specific Radiological Dose and Risk Characterization for Sewer Sediment: Current/Future Sewer Maintenance Worker

Property	Sewer Sediment Location	Risk with Background	Dose & Risk Above Background [a]	
		Max. CR (unitless)	Max. Dose (mrem/yr)	Max. CR (unitless)
Background	All Background Locations	NA	0.01	9.2E-09
SLDS (Sitewide)	All SLDS Locations	9.1E-09	0	<BKGD
Plant 1	SLD123489	8.4E-09	0	<BKGD
	SLD123490	8.0E-09	0	<BKGD
	SLD123491	1.5E-08	0.01	5.8E-09
	SLD123492	9.1E-09	0	<BKGD
	SLD123493	6.4E-09	0	<BKGD
	SLD123494	1.5E-08	0.01	5.8E-09
	SLD123495	5.2E-09	0	<BKGD
	SLD123496	8.4E-09	0	<BKGD
	SLD123497	1.1E-08	0	1.8E-09
	SLD123498	6.3E-09	0	<BKGD
Plant 2	SLD123503	4.1E-09	0	<BKGD
	SLD123504	6.8E-09	0	<BKGD
	SLD123505	6.4E-09	0	<BKGD
	SLD123740	6.5E-09	0	<BKGD
	SLD123741	5.8E-09	0	<BKGD
	SLD123742	1.1E-09	0	<BKGD
	SLD123743	7.0E-09	0	<BKGD
	SLD123744	7.0E-09	0	<BKGD
	SLD123749	6.1E-09	0	<BKGD
	SLD123750	7.0E-09	0	<BKGD
	SLD123751	6.6E-09	0	<BKGD
Plant 6	SLD123746	1.1E-08	0	1.8E-09
	SLD123747	6.9E-09	0	<BKGD
	SLD123748	7.0E-09	0	<BKGD
Plant 7	SLD123745	8.5E-09	0	<BKGD
DT-11	SLD123488	5.5E-09	0	<BKGD

[a] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table K-19B. Sitewide and Location-Specific Metals Risk Characterization for Sewer Sediment: Current/Future Sewer Maintenance Worker

Property	Sewer Sediment Location	Total Property CR [a]	Total Property HI [a]
Background	All Background Locations	4.0E-07	0.0029
SLDS (Sitewide)	All SLDS Locations	1.9E-07	0.0012
Plant 1	SLD123489	2.3E-07	0.0014
	SLD123490	3.6E-07	0.0022
	SLD123492	2.0E-07	0.0012
	SLD123493	2.7E-07	0.0017
	SLD123494	1.7E-07	0.0010
	SLD123495	1.1E-07	0.00066
	SLD123496	6.7E-07	0.0042
	SLD123497	8.7E-08	0.00054
	SLD123498	1.1E-07	0.00069
	SLD123503	1.7E-07	0.0011
	SLD123504	1.5E-07	0.00093
	SLD123505	1.7E-07	0.0010
Plant 2	SLD123740	7.5E-08	0.00047
	SLD123742	1.5E-07	0.00096
	SLD123743	6.7E-08	0.00042
	SLD123744	8.3E-08	0.00051
	SLD123749	5.1E-08	0.00032
	SLD123750	1.1E-07	0.00069
Plant 6	SLD123746	7.1E-08	0.00044
	SLD123747	3.9E-08	0.00025
	SLD123748	1.0E-07	0.00064
Plant 7	SLD123745	1.8E-07	0.0011
DT-8	SLD123488	1.5E-07	0.00096

[a] Incidental ingestion of arsenic was the predominant contributor to all total CRs and HIs.

Gray shading indicates that the CR or HI exceeds the corresponding background CR or HI. The non-shaded CRs and HIs are within the range of background.

Table K-20A. Sitewide and Location-Specific Radiological Dose and Risk Characterization for Soil Adjacent to Sewer Lines: Current/Future Sewer Utility Worker

Property	Soil Locations Adjacent to Sewers	Risk with Background [a,b]	Dose & Risk Above Background [b]	
		Max. CR (unitless)	Max. Dose (mrem/yr)	Max. CR (unitless)
Background	All Background Locations	NA	0.3	2.6E-07
SLDS (Sitewide)	All SLDS Locations	8.6E-06	11.7	8.3E-06
Plant 1	SLD124538	1.8E-07	<BKGD	<BKGD
	SLD124540	6.0E-07	0.7	3.4E-07
	SLD124542	1.6E-07	<BKGD	<BKGD
	SLD124544	2.6E-07	0.1	0.0E+00
	SLD124546	1.8E-07	<BKGD	<BKGD
	SLD124548	2.1E-07	0	<BKGD
	SLD124550	2.0E-07	0	<BKGD
	SLD124552	1.5E-07	<BKGD	<BKGD
	SLD124554	1.4E-07	<BKGD	<BKGD
	SLD124556	1.6E-07	<BKGD	<BKGD
	SLD124558	1.6E-07	<BKGD	<BKGD
	SLD124560	2.0E-07	0	<BKGD
	SLD124564	1.8E-07	<BKGD	<BKGD
	SLD124566	2.2E-07	0	<BKGD
	SLD124568	1.6E-07	<BKGD	<BKGD
	SLD124570	2.1E-07	0	<BKGD
	SLD125283	2.0E-07	0	<BKGD
	SLD125521	4.2E-07	0.7	1.6E-07
Plant 2	SLD124574	1.9E-07	0	<BKGD
	SLD124576	1.7E-07	<BKGD	<BKGD
	SLD124578	1.5E-07	<BKGD	<BKGD
	SLD124580	4.5E-07	0.7	1.9E-07
	SLD125385	2.5E-07	0	<BKGD
Plant 6	HTZ88929	1.1E-05	15	1.1E-05
	HTZ88930	1.4E-06	2.7	1.1E-06
	SLD127572	6.6E-07	0.7	4.0E-07

Table K-20A. Sitewide and Location-Specific Radiological Dose and Risk Characterization for Soil Adjacent to Sewer Lines: Current/Future Sewer Utility Worker

Property	Soil Locations Adjacent to Sewers	Risk with Background [a,b]	Dose & Risk Above Background [b]	
		Max. CR (unitless)	Max. Dose (mrem/yr)	Max. CR (unitless)
Plant 7/DT-12	SLD124586	2.2E-07	0	<BKGD
	SLD131146	7.5E-07	0.7	4.9E-07
	SLD131156	3.0E-07	0.1	4.0E-08
	SLD131166	1.9E-07	0	<BKGD
	SLD131176	3.7E-07	0.7	1.1E-07
	SLD93275	1.9E-04	259	1.9E-04
	SLD93276	5.5E-05	75	5.5E-05
	SLD93277	8.5E-05	115	8.5E-05
DT-2 Levee	SLD120945	2.1E-05	29	2.1E-05
	SLD120946	1.4E-05	20	1.4E-05
	SLD120947	2.2E-05	30	2.2E-05
	SLD120948	9.8E-07	0.7	7.2E-07
DT-8 and DT-11	SLD124590	2.0E-07	0	<BKGD
	SLD124592	1.1E-07	<BKGD	<BKGD
	SLD124594	1.7E-07	<BKGD	<BKGD

[a] Dose and risk calculations for all properties assume no ground cover for the sewer utility worker.

[b] For the site, dose and risk above background are calculated as the difference between dose and risk with background and background dose and risk. The values reported in the "Background" row, are the actual dose and risk estimated for background used in the calculations of dose and risk above background.

NA - Not applicable.

<BKGD - Indicates that dose or risk is within the range of background.

Table K-20B. Sitewide and Location-Specific Metals Risk Characterization for Soil Adjacent to Sewer Lines: Current/Future Sewer Utility Worker

Property	Soil Locations Adjacent to Sewers	Total Property CR [a]	Total Property HI [a]
Background	All Background Locations	4.5E-08	0.0072
SLDS (Sitewide)	All SLDS Locations	8.2E-08	0.036
Plant 1	SLD124538	1.9E-08	0.0031
	SLD124540	4.0E-07	0.069
	SLD124542	2.1E-08	0.0033
	SLD124544	4.5E-08	0.0073
	SLD124546	2.6E-07	0.041
	SLD124548	8.9E-08	0.35
	SLD124550	5.6E-08	0.0089
	SLD124552	7.7E-08	0.012
	SLD124554	3.4E-08	0.011
	SLD124556	4.3E-08	0.0079
	SLD124558	6.4E-08	0.010
	SLD124560	9.3E-08	0.016
	SLD124564	2.7E-08	0.0047
	SLD124566	7.3E-08	0.012
	SLD124568	3.4E-08	0.0055
	SLD124570	1.8E-07	0.028
	SLD125283	1.8E-08	0.0029
	SLD125521	1.3E-07	0.027
Plant 2	SLD124574	3.2E-08	0.0054
	SLD124576	1.1E-08	0.0019
	SLD124578	3.9E-08	0.0062
	SLD125385	7.3E-08	0.012
Plant 6	SLD127572	4.6E-08	0.0074
Plant 7N/DT-12	SLD124586	3.0E-08	0.0081
DT-8 and DT-11	SLD124590	1.7E-08	0.0028
	SLD124592	1.4E-08	0.0023
	SLD124594	3.9E-08	0.0062

[a] CR and HI calculations for all properties assume no ground cover. Incidental ingestion of arsenic was the predominant contributor to all total CRs and HIs.

Gray shading indicates that the CR or HI exceeds the corresponding background CR or HI. The non-shaded CRs and HIs are within the range of background.

Table K-20C. Sitewide and Location-Specific Risk Characterization for Lead in Soil Adjacent to Sewer Lines: Current/Future Sewer Utility Worker

Property	Soil Locations Adjacent to Sewers	Predicted 95th Percentile Blood Lead Concentration Among Fetuses of Adult Utility Workers (µg/dl) [a]	Probability That Fetal Blood Lead Levels Will Exceed 10 µg/dL [a]
Background	All Background Locations	2.7	0.0051%
SLDS (Sitewide)	All SLDS Locations	2.8	0.0065%
Plant 1	SLD124538	2.4	0.0023%
	SLD124540	3.4	0.027%
	SLD124542	2.4	0.0026%
	SLD124544	2.4	0.0026%
	SLD124546	2.4	0.0023%
	SLD124548	2.6	0.0045%
	SLD124550	2.5	0.0033%
	SLD124552	2.4	0.0023%
	SLD124554	2.4	0.0023%
	SLD124556	2.6	0.0036%
	SLD125283	2.4	0.0022%
	SLD124558	2.4	0.0025%
	SLD124560	2.9	0.009%
	SLD125521	2.9	0.008%
	SLD124564	2.4	0.0022%
	SLD124566	2.4	0.0025%
	SLD124568	2.4	0.0022%
	SLD124570	3.1	0.013%
Plant 2	SLD124574	2.4	0.0022%
	SLD124576	7	2%
	SLD124578	2.4	0.0022%
	SLD125385	2.5	0.0028%
Plant 6	SLD127572	3.3	0.02%
Plant 7N/DT-12	SLD124586	2.6	0.0040%
DT-8 and DT-11	SLD124590	2.4	0.0022%
	SLD124592	2.4	0.0022%
	SLD124594	2.4	0.0022%

[a] ALM calculations assume no ground cover for the sewer utility worker.

Gray shaded values exceed corresponding background levels of 2.9 µg/dl for fetal PbB concentration and a 0.0096% probability of exceeding the fetal PbB target 10 µg/dl. The non-shaded values are within the range of background.

Table K-21. Potential Contaminants of Concern for Soil in the Inaccessible Soil Operable Unit

Chemical Constituents [a]	Radiological Constituents
Arsenic	Ac-227
Cadmium	Pa-231
Uranium metal	Ra-226
	Ra-228
	Th-228
	Th-230
	Th-232
	U-235
	U-238

[a] Applicable to soil in the uranium-ore processing area: Plants 2, 6, and 7; DT-10; and portions of DT-9, DT-12, Hall Street, Mallinckrodt Street, and Destrehan Street (USACE 1998a).

Table K-22. Potential Contaminants of Concern for Sewer Sediment and Soil Adjacent to Sewers in the Inaccessible Soil Operable Unit

Chemical Constituents	Radiological Constituents
Arsenic	Ac-227
Cadmium	Pa-231
Cobalt	Ra-226
Copper	Ra-228
Lead	Th-228
Manganese	Th-230
Molybdenum	Th-232
Nickel	U-235
Selenium	U-238
Thorium metal	
Uranium metal	
Vanadium	
Zinc	

Note: Sewer sediment and soil adjacent to sewers had not been characterized for metals; therefore, all metals associated with pitchblende and domestic ores used in the former MED/AEC uranium-ore processing operations (DOE 1993) were identified as PCOCs in sewer sediment and soil adjacent to sewers.

ATTACHMENT K-1

Evaluation of Hypothetical Resident Gardener Exposures at the St. Louis Downtown Site Inaccessible Soil Operable Unit

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ATTACHMENT K-2

Data Comparisons with Residential Preliminary Remediation Goals

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APPENDIX L

Radiological and Metals Analytical Data Summaries and Figures for Accessible Soil by Property

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APPENDIX M

Exposure Point Concentration Calculations for Radiological COPCs

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APPENDIX N

Exposure Point Concentration Calculations for Metal COPCs

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APPENDIX O

RESRAD Model Outputs: Radiological Dose and Risk Calculations for Inaccessible Soil and Sewer Soil Borehole Locations

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APPENDIX P

RESRAD-BUILD Model Outputs: Radiological Dose and Risk Calculations for Exterior Building Surfaces

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APPENDIX Q

Dose and Risk Calculations for Exposures to Metals COPCs in Inaccessible Soil, Sewer Sediment, and Soil Adjacent to Sewer Lines

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