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FEASIBILITY STUDY FOR THE ST. LOUIS DOWNTOWN SITE

ST. LOUIS, MISSOURI

APRIL 1998

prepared by
U.S. Army Corps of Engineers, St. Louis District Office, Formerly Utilized Sites Remedial Action Program

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ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission
ALARA	as low as reasonably achievable
AR	Army Regulation
ARAR	applicable or relevant and appropriate requirement
AS	accessible soils
BNAE	base/neutral and acid extractable
BRA	baseline risk assessment
BS	buildings and structures
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
CFR	Code of Federal Regulations
CWA	Clean Water Act
dpm	disintegration per second
dBA	decibel
DCG	derived concentration limit
DOCHMC	Department of Community Health and Medical Care
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of Interior
EIS	Environmental Impact Statement
EMS	Emergency Medical Services
EPA	U.S. Environmental Protection Agency
ER	Engineer Regulation
ESA	Endangered Species Act
ESP	electrostatic precipitator
FFA	Federal Facilities Act
FR	Federal Register
FS	feasibility study
FUSRAP	Formerly Utilized Sites Remedial Action Program
FWS	Fish and Wildlife Service
FY	fiscal year
GRA	general response action
GW	groundwater
HEPA	high-efficiency particulate air
HHPRG	human health preliminary remediation goal
HISS	Hazelwood Interim Storage Site
HUD	U.S. Department of Housing and Urban Development
Inc.	Incorporated
ISA	initial screening of alternatives
MCL	maximum contaminant level
MDNR	Missouri Department of Natural Resources

ACRONYMS AND ABBREVIATIONS (continued)

MED	Manhattan Engineer District
MSL	mean sea level
NAAQS	National Ambient Air Quality Standards
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NORM	naturally-occurring radioactive material
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
O&M	operations and maintenance
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Act
OSWER	Office of Solid Waste and Emergency Response
PAH	polyaromatic hydrocarbon
PCB	polychlorinated biphenyl
PCOC	potential contaminant of concern
POTW	publicly-owned treatment works
PP	proposed plan
PRG	preliminary remediation goal
ppb	parts per billion
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
RESRAD	RESidual RADiation computer modeling system
RI/FS	remedial investigation/feasibility study
RME	reasonable maximum exposure
ROD	Record of Decision
IS	inaccessible soils
s	second
SARA	Superfund Amendments and Reauthorization Act
SHPO	State Historic Preservation Office
SHRTSC-NCEA	Superfund Health Risk Technical Support Center – National Center for Environmental Assessment of EPA
SLAPS	St. Louis Airport Site
SLDS	St. Louis Downtown Site
TBC	to be considered
TCE	trichloroethylene
TCLP	toxicity characteristic leaching procedure
TOC	toxic organic compound
UMTRAP	Uranium Mill Tailings Remedial Action Project
UMTRCA	Uranium Mill Tailings Radiation Control Act

ACRONYMS AND ABBREVIATIONS (continued)

USACE	U.S. Army Corps of Engineers
VOC	volatile organic compound
WL	working level
WQC	Water Quality Criteria

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EXECUTIVE SUMMARY

The St. Louis site, as shown in Figure ES-1, comprises multiple properties located in two distinct areas: downtown St. Louis and land proximate to Lambert-St. Louis International Airport. From 1942 to 1957, Mallinckrodt Inc. in downtown St. Louis separated uranium from ores. These processing activities, conducted under Manhattan Engineer District (MED) and U.S. Atomic Energy Commission (AEC) contracts, contaminated portions of the property and buildings with radium, thorium, and uranium. Uranium-bearing process residues from Mallinckrodt processing operations were subsequently stored at the St. Louis Airport Site (SLAPS) and the Latty Avenue Properties. Relocation and storage of these processed wastes at SLAPS and the Latty Avenue Properties resulted in the subsequent contamination of the SLAPS vicinity properties. St. Louis site properties on the National Priorities List (NPL) include SLAPS, Hazelwood Interim Storage Site (HISS), and Futura Coatings Properties (Figure ES-1). The downtown area properties are not on the NPL but are included in the remediation effort since the waste materials that contaminated the NPL sites were generated at the St. Louis Downtown Site (SLDS). This feasibility study (FS) was prepared to address the contamination at SLDS, including vicinity properties, but excluding inaccessible soils. Inaccessible soils are contaminated soils that are located beneath buildings and other permanent structures such as railroads. These overlying structures are active industrial and commercial facilities or active transportation corridors. Inaccessible soils are excluded from the scope of this FS because remediation of these soils at this time would result in severe economic dislocations and community disruptions.

Actions taken at the site will be conducted under the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was initiated to identify and remediate or otherwise control sites where residual radioactivity remains from activities conducted under contract to MED and AEC during the early years of the nation's atomic energy program or from commercial operations that Congress has added to the FUSRAP sites. Responsibility for remediation of radioactive and commingled chemical contamination identified at the site has been partitioned between the United States Army Corps of Engineers (USACE) and the U.S. Environmental Protection Agency (EPA). A Federal Facilities Agreement (FFA) (DOE 1990a) negotiated by EPA Region VII and the U.S. Department of Energy (DOE) outlines those responsibilities. In general, the documentation for remedial activities is to be developed in consultation with EPA. The FFA addresses the following types of materials:

- All wastes, including but not limited to radiologically contaminated wastes, resulting from or associated with uranium manufacturing or processing activities conducted at SLDS.
- Other chemical or radiological wastes that have been mixed or commingled with wastes resulting from or associated with uranium manufacturing or processing activities conducted at SLDS.

USACE is conducting a remedial investigation/feasibility study (RI/FS) process for the St. Louis site in accordance with procedures developed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). A proposed plan (PP) is published separately

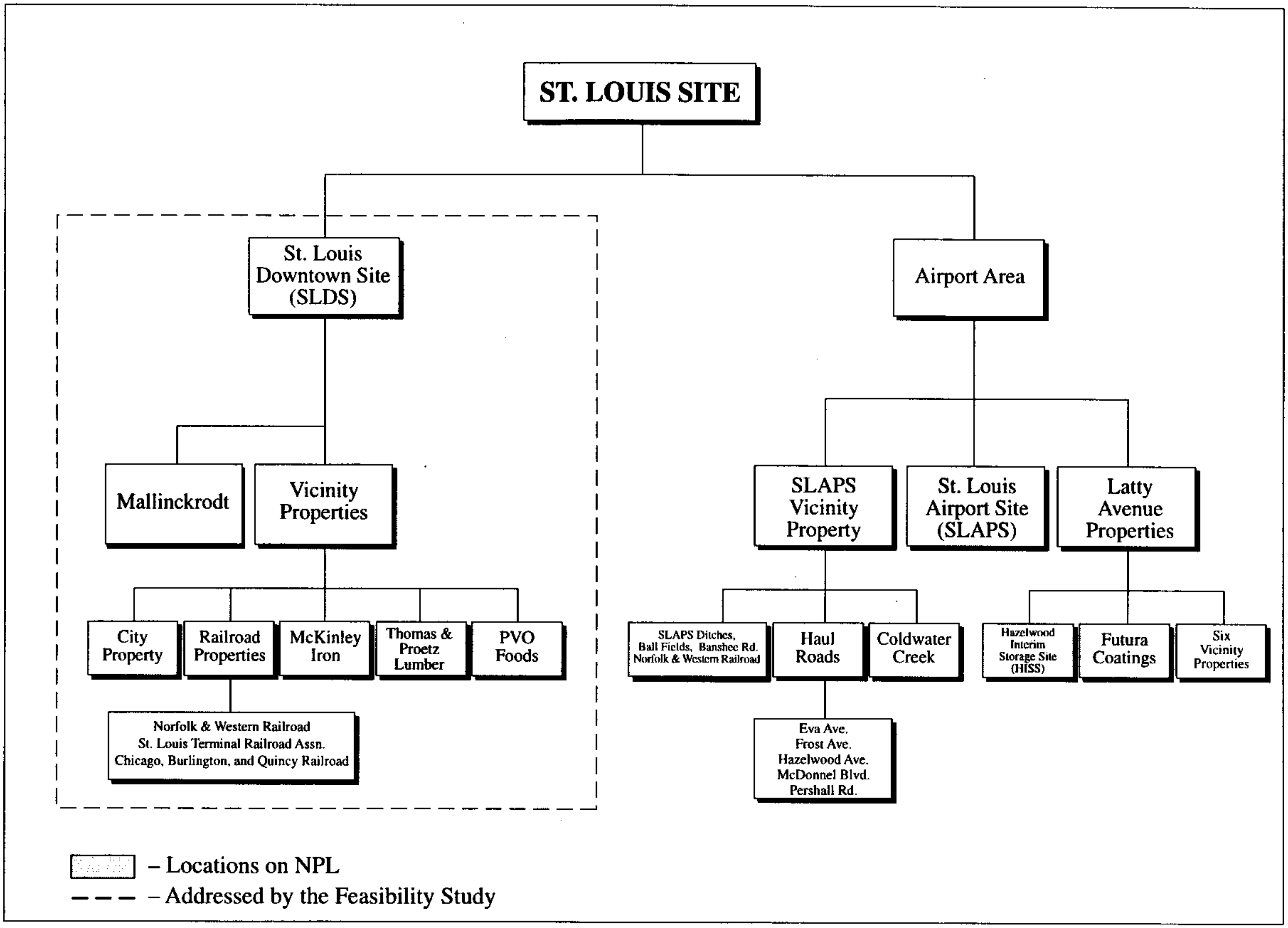

Figure ES-1. Schematic Representation of the St. Louis Site but is considered an integral part of the RI/FS process. The PP highlights information from the FS and identifies the preferred alternative. It is the fourth major document in the RI/FS package. The RI report, a baseline risk assessment (BRA), and the FS are the primary evaluation documents prepared to summarize the findings of the RI/FS. The RI/FS process will, after regulatory and public review, conclude with the issuance of a Record of Decision (ROD) that will identify the remedy selected for the contamination present at SLDS. It is the position of USACE that the CERCLA process is functionally equivalent to the requirements of the National Environmental Policy Act.

ES.1 NATURE AND EXTENT OF MED-RELATED RADIOLOGICAL AND CHEMICAL CONTAMINATION

Radiological and chemical characterization surveys and field investigations were conducted at the St. Louis site from 1977 through 1992 to determine the nature and extent of contamination and to characterize the geological and hydrogeological features of the properties.

Many of the organic and non-radioactive inorganic chemicals detected at SLDS have not yet been attributed to one source, industry, or event due to the history and diverse nature of the industries located at the downtown site. The same holds true for radionuclides. Potential sources for radionuclides at SLDS include MED/AEC uranium handling activities, Mallinckrodt Inc., materials processing, and coal combustion residue used as fill.

The BRA used all available analytical data to characterize the risks associated with the St. Louis site. Data were obtained from areas at SLDS on organic and non-radioactive inorganic chemicals and radionuclides not necessarily associated with MED/AEC uranium handling activities. The presence of multiple chemical and radionuclide industry sources complicates the assessment of SLDS. Consistent with the FFA, any non-MED/AEC contaminated areas are not considered within the scope of this SLDS FS. A contaminated area at SLDS must be attributed to MED/AEC uranium processing activities to be within the scope of this action. The SLDS FS approach is to address only radiological and/or chemical contamination that poses potentially unacceptable risks. For the purposes of this FS, potential contaminants of concern (PCOCs) identified in the BRA can be viewed as radiological PCOCs and any non-radiological chemicals commingled in media impacted by MED/AEC activities.

The results presented in Table ES-1 summarize the nature and extent of contamination at SLDS. Radium, thorium, uranium, and their progeny are the primary radiological contaminants at SLDS. Surface and subsurface soil contamination at SLDS exceeds various radiological concentration and dose or risk standards set forth by the EPA and the U.S. Nuclear Regulatory Commission (NRC).

Groundwater radiological contamination above background was identified at SLDS. However, the low-yield nature of the upper hydrostratigraphic unit, the fact that contamination is bound on clayey soils, and the low solubility of contaminants in water precludes the use of pump and treat as a treatment option. Removal of contaminated source materials through excavation of soil materials would be more effective in long-term protection of groundwater than pumping and treating.

Table ES-1. Nature and Extent of Radioactive Contamination in the Downtown St. Louis Area

Media	Contaminant Type	Mallinckrodt	Vicinity Properties
Soils and sediments	radium, thorium, uranium	Surface and subsurface soils exceed radiological criteria. Some contaminated soils are covered by buildings and other manmade structures. Volume is estimated at 80,000 m^3 (105,000 yd^3) (BNI 1997).	Surface and subsurface soils exceed radiological criteria. Some contaminated soil on railroad property is covered by railroad beds. Volume is estimated at 11,000 m^3 (15,000 yd^3) (BNI 1997).
Structures and Buildings	radium, thorium, uranium	Fixed alpha and beta-gamma contamination on surfaces above criteria. Elevated radon levels and external gamma exposure rates inside buildings.	No buildings exceed surface criteria.
Groundwater	radium, thorium, uranium	Two onsite wells contain high levels of uranium adjacent to uranium processing plant. One other well shows levels of radium slightly above safe drinking water regulations in 40 CFR 141.	None of the vicinity property groundwater wells exceed applicable radiological criteria.

Under current (ie, existing use) risk scenarios, SLDS is generally within the acceptable risk range EPA has specified for protection of human health for all scenarios considered by the BRA except the construction worker scenario. The acceptable exposure levels are generally concentration levels that represent an excess upper-bound lifetime cancer risk to an individual of between 10^{-6} and 10^{-4} using information on the relationship between dose and response. Construction worker levels exceed this general range if one assumes the absence of required worker protection measures. Under plausible future use assumptions, potential cancer risks may become higher for members of the public than the acceptable range for the protection of human health. Accordingly, the overall objective of remedial action at SLDS is to eliminate or minimize the potential future health risks posed by the MED/AEC site-related contamination under assumed future uses of the site.

ES.2 ALTERNATIVES DEVELOPMENT

The remedial action objectives for SLDS are to:

- reduce risk to workers to within the CERCLA target risk range;
- eliminate or minimize potential for humans or biota to contact, ingest, or inhale soil or water containing PCOCs;
- eliminate or minimize volume, toxicity, and mobility of contaminants;
- eliminate or minimize the potential for migration of radioactive materials off-site;

- comply with chemical, action and location specific ARARs; and
- eliminate or minimize potential exposure to external gamma radiation.

Remedial technologies identified as having potential application for SLDS were screened for technical feasibility. These technologies are evaluated in the Initial Screening of Alternatives document (SAIC 1992).

ES.3 DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

Remedial technologies relevant to SLDS that were retained after the initial screening are listed in Table ES-2. Remedial actions were formulated using these technologies to address accessible contaminated media at SLDS. For the purpose of evaluating remedial actions common to a particular media or circumstance, contaminated media were divided into the following categories:

- accessible soils and sediment,
- buildings and structures, and
- groundwater.

Table ES-2. Remedial Technologies Retained from Initial Screening

Media	General Response Actions				
	Institutional Controls	Removal	Containment	Treatment	Disposal
Contaminated soil and sediment	Deed or land use restriction; access restriction; monitoring	Partial or total excavation	Clay or multimedia cap or soil cover	Onsite or off-site; physical or chemical	Onsite land encapsulation; off-site disposal
Buildings and Structures	Deed or land use restrictions; access restrictions; ambient air monitoring	Partial demolition; complete demolition	Clay or multimedia cap or soil cover over rubble	Physical or chemical decontamination	Building debris to onsite land encapsulation or off-site disposal
Groundwater	Deed or land use restrictions, groundwater monitoring	Injection and/or extraction wells; source material removal	Slurry walls, in situ grouting	Air stripping, carbon adsorption, ion exchange, evaporative recovery, and ancillary processes	Surface water discharge, discharge to publicly owned treatment works

Potential remedial actions for each category were evaluated by using effectiveness, implementability, and cost criteria. The results of this screening were used to assemble the appropriate unit-specific remedial actions into five alternatives:

- Alternative 1 – No Action,
- Alternative 2 – Institutional Controls and Site Maintenance,
- Alternative 3 – Consolidation and Capping,
- Alternative 4 – Partial Excavation and Disposal,
- Alternative 5 – Complete Excavation and Disposal, and
- Alternative 6 – Selective E Alternatives 3, 4, 5, and 6, institutional controls and monitoring would be maintained for the Excavation and Disposal.

Treatment is not included in the Alternative descriptions, but would be a conditional part of the excavation alternatives. No data is available on the effectiveness of treatment for SLDS soils, but if a treatment technology is demonstrated to be cost effective before completion of remedial activities, it may be incorporated into the remedy.

ES.4 DETAILED ANALYSIS OF ALTERNATIVES

Alternative 1, No Action, is required by the National Contingency Plan (NCP) and by CERCLA guidance to be retained throughout the entire feasibility study process to provide a baseline against which all other remedial alternatives are compared. The no-action alternative is not a suitable alternative at the SLDS because it would not achieve the threshold criteria of being protective of human health and the environment. Because this alternative is unacceptable, CERCLA guidance will dictate which of the remaining alternatives will be implemented.

Alternative 2 is the only non-disposal alternative that is protective of human health and the environment. Costs associated with institutional control and site maintenance are higher than the no-action alternative but are substantially less than disposal alternatives.

Alternatives 3 through 6 require excavation and/or disposal of large volumes of contaminated soil. Under Alternative 3, onsite consolidation of waste is followed by capping onsite. Capping is unique to Alternative 3.

The six alternatives for downtown St. Louis and applicable remedial actions are presented in Table ES-3. This table summarizes the nature of the remediation to be performed in order to achieve protection of human health and the environment for each alternative.

The selected alternatives were each evaluated against the CERCLA criteria and then compared with each other. Alternative 1, which does not achieve protection of human health or the environment and does not comply with applicable or relevant and appropriate requirements (ARARs), is only included for comparison purposes because it provides the baseline case. Alternative 2 would provide long-term protectiveness if deed and land-use restrictions can be effectively implemented to limit access and prevent future exposure but is least protective from residual risk because it leaves all contaminated media in place. Alternative 2 would meet ARARs by implementation of institutional controls.

Alternatives 3, 4, 5, and 6 are more protective than Alternative 2 because they involve removing accessible soils, sediment, and residual surface contamination in buildings. In

Table ES-3. Alternatives for Remediation of SLDS

Alternative	Alternative Description
1. No Action	No changes from current status
2. Institutional Controls	Continued institutional controls and site maintenance
3. Consolidation and Capping	Accessible soils exceeding 5 pCi/g Ra-226 or Th-230 (and Ra-228 or Th-232), in the top 15 cm and 15 pCi/g in deeper soil or 50 pCi/g U-238 (composite criteria) would be removed and consolidated onto a nearby downtown location. Institutional controls and monitoring would be maintained for contaminated soil under structures and the railroad beds until the remedy for inaccessible soils is determined. Buildings exceeding surface criteria would be decontaminated or dismantled.
4. Partial Excavation and Disposal	Accessible soils exceeding the criteria in Alternative 3 in the top 2 ft would be removed. Soil deeper than 2 feet would be excavated if it exceeded 50 pCi/g Ra-226, 100 pCi/g Th-230, or 150 pCi/g U-238 (ALARA criteria, based on risk analysis presented in Appendix C). Soil beneath buildings and the railroad beds would be left in place and institutional controls and monitoring would continue until the remedy for inaccessible soils is determined. Contaminated buildings would be decontaminated or dismantled.
5. Complete Excavation and Disposal	Soil would be removed to the same criteria as in Alternative 3. The difference between Alternative 3 and Alternative 5 is that Alternative 5 would send the excavated soil to off-site disposal. Contaminated buildings would be decontaminated or dismantled.
6. Selective Excavation and Disposal	Similar to Alternative 4, except that the depth of excavation to the more stringent composite criteria would be extended to 4–6 ft. Material below the ALARA criteria may be used as backfill below the 4–6 ft depth. Only approved off-site borrow would be used to fill in the excavations from 4–6 ft to grade.

Alternatives 3, 4, 5, and 6, institutional controls and monitoring would be maintained for the inaccessible soils above criteria until the remedy for inaccessible soils is determined. Alternatives 4 and 6 may reuse soil below 50 pCi/g Ra-226, 100 pCi/g Th-230 and 150 pCi/g U-238 (ALARA criteria) at depths greater than 2 ft in Alternative 4 and 4 to 6 feet in Alternative 6. Greater protectiveness through long-term effectiveness and permanence would be achieved at locations where soils and sediments are removed. Long-term controls would be required for the capped location. These alternatives would comply with ARARs for all remediated soils but may require supplemental standards for some inaccessible soils and for groundwater in accordance with 40 CFR 192. Supplemental standards are applicable when it can be demonstrated that: contamination left in place presents no significant exposure hazard; the remedial action would pose a risk of injury to workers or to members of the public; the remedial action would cause environmental harm that is excessive compared to the health benefits; or remedial costs are unusually high. For the inaccessible soil locations, institutional controls would be used to restrict access and thereby control future risk until the remedy for inaccessible soils is selected. Inaccessible soil excavation would require Mallinckrodt Inc. to demolish several of its buildings and structures and railroad companies to remove tracks.

The soil excavation, with the off-site disposal options of Alternatives 4, 5, and 6, are more protective than Alternative 3 in terms of residual risk and long-term effectiveness and permanence because radiologically contaminated soils and sediments and residual surface contamination in buildings would be permanently removed from SLDS. Alternatives 4 and 6 would comply with ARARs through invoking supplemental standards for soil below the depth of remediation to the composite criteria.

Each of the alternatives, except the No Action Alternative is protective of human health and the environment. The degree of protectiveness and permanence is a function of whether and to what extent an alternative uses containment, removal, and institutional controls strategies. No Action could not be implemented at SLDS because it would not achieve the threshold criterion of being protective of human health and the environment. Alternative 2 would use institutional controls to achieve overall protection of human health and the environment. Alternatives 3, 4, 5, and 6 would use engineered and institutional controls to achieve overall protection of human health and the environment from soil and groundwater contamination. Under Alternatives 4, 5, and 6 contaminated materials would be excavated and disposed offsite with the potential that institutional controls may eventually be removed in the remediated areas. Alternatives 2, 3, 4, 5, and 6 would reduce to protective levels the long-term risks associated with existing contamination.

In comparison the following relationships are noted:

- The risk of construction worker related accidents and fatalities is about the same for Alternatives 3 and 5, less for Alternatives 4 and 6, and least for Alternative 2.

- The transportation of waste long distances from the site involves risk of injuries and fatalities from transportation accidents that are much greater than any radiological cancer risk resulting from exposure to contaminated material.

- The risk of worker and public transportation fatality increases with increasing excavated soil volume and approved backfill volume. Alternative 2 presents the lowest risk, followed by Alternatives 3, 4, 6 and 5 in order of increasing risk.

- The risk of a traffic fatality is greater for truck transport than for rail transport given the same hauling distance; and,

- The projected number of traffic fatalities is greater for members of the public than for members of the transportation crew for a given scenario.

For the excavation and construction workers, overall protectiveness is highest for Alternative 4 in that it provides the lowest non-radiological occupational risk of fatality (approximately 0.002) due to less movement and handling of soil. In comparison, Alternatives 3, 5 and 6 pose a greater risk with Alternative 3 having a fatality risk of 0.0055 and Alternative 5 having a fatality risk of 0.0056.

Protection of community and workers during transportation and time required to complete remedial actions are dependent on the disposal options. The related fatality incidence ranges from 0.013 to 0.086.

Alternatives 3, 4, 5 and 6 would reduce contaminant mobility by disposal. Capping or encapsulation as in Alternative 3 would prevent infiltration of precipitation through contaminated materials. Furthermore, Alternative 3 would eliminate contaminant migration by means of wind erosion or surface runoff, and would prevent human exposure to the waste. Alternatives 3, 4, 5, and 6 provide the greatest degree of protection from residual risk because contaminated materials identified as posing potentially unacceptable risks to human health and the environment are ultimately removed from their present locations and permanently isolated in an engineered disposal facility. All current potential exposure pathways are eliminated by these alternatives.

Alternative 1 does not control groundwater use. Alternative 2 restricts the use of groundwater through use of institutional controls. Alternatives 3, 4, 5, and 6 remove the source of potential future groundwater contamination from below the water table. Alternative 2 is more effective than Alternative 1 in controlling access to contamination. Alternatives 3, 4, 5, and 6 are as effective as Alternative 2 in controlling access to groundwater contamination and are more effective than Alternatives 1 and 2 at minimizing potential for future groundwater contamination and are comparable to each other in this regard.

Alternative 2 is the least protective (other than No Action) because it leaves all contaminated media in place, but still is protective as a result of institutional controls and site maintenance. Alternative 3 is more protective than Alternative 2 because it consolidates the soils in a central location thus reducing the opportunity for exposure. Alternative 4 is more protective than Alternative 3 because it removes the highest risk soil from the site. Alternative 6 is more protective than Alternative 4 because it removes contamination at lower concentrations to a greater depth than Alternative 4. Alternative 5 is the most protective because it removes the most contaminated soil from the site. Each alternative would rely on continued institutional controls to maintain protectiveness. Environmental monitoring and institutional controls are used to achieve the inaccessible soil protectiveness of the excavation alternatives until the remedy for inaccessible soils is determined.

The total 30-year costs for the six alternatives are:

Alternative 1 – No Action	$22 million
Alternative 2 – Institutional Controls and Site Maintenance	$29 million
Alternative 3 – Consolidation and Capping	$100 million
Alternative 4 – Partial Excavation and Disposal	$92 million
Alternative 5 – Complete Excavation and Disposal	$140 million
Alternative 6 – Selective Excavation and Disposal	$114 million

The differences in costs among alternatives are very significant and increase primarily with the amount of contaminated soil to be excavated and the type of disposal facility chosen. To provide comparability across the alternatives, estimated costs are based on addressing all impacted soil at the site (accessible and inaccessible) for each alternative. Because inaccessible soils must ultimately be addressed, this approach provides a reasonable mechanism for bounding total remediation costs while not substantively impacting the alternatives analysis.

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1. INTRODUCTION

1.1 BACKGROUND

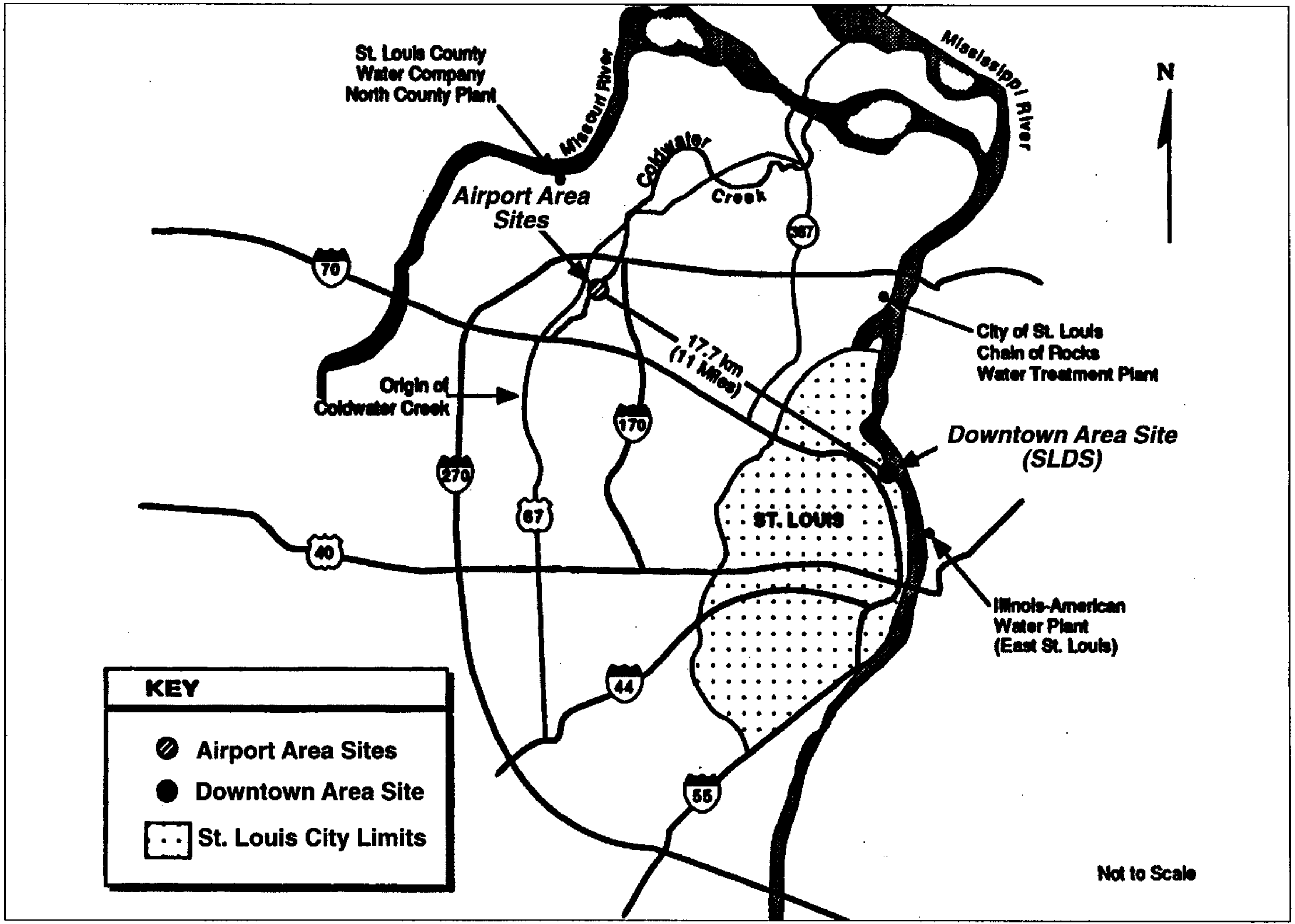
The U.S. Army Corps of Engineers (USACE) is administering a program for the management and remediation of radioactive contamination at the St. Louis site in St. Louis, Missouri. In 1974, the U.S. Congress authorized the Atomic Energy Commission (AEC), a predecessor to the U.S. Department of Energy (DOE), to institute the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was initiated to identify and remediate mandated sites where residual radioactivity remains from activities conducted under contract to the Manhattan Engineer District (MED) and AEC during the early years of the nation's atomic energy program, or from other operations assigned via congressional legislation. Congress authorized USACE to take over management of FUSRAP in October 1997.

Mallinckrodt Inc., (Mallinckrodt) in downtown St. Louis separated uranium from ore from 1942 to 1957. These processing activities, conducted under MED and AEC contracts, resulted in radioactive contamination at Mallinckrodt in downtown St. Louis. Subsequent disposal and relocation of processing wastes resulted in radioactive contamination at other locations near the Lambert-St. Louis International Airport.

The St. Louis site consists of two general locations, the downtown area and the airport area (Figure 1-1). The downtown area consists of the Mallinckrodt facilities where the ore was processed, and adjacent vicinity properties. Taken together, this group of properties is known as the St. Louis Downtown Site (SLDS). The airport area consists of the St. Louis Airport Site (SLAPS), SLAPS vicinity properties, and Latty Avenue properties (Figure 1-2). Some component sites of the airport area—SLAPS and two Latty Avenue properties: Hazelwood Interim Storage Site (HISS) and Futura Coatings—are on the U.S. Environmental Protection Agency's (EPA's) National Priorities List (NPL). The NPL is a list of sites identified for remedial action under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). The downtown area properties are not on the NPL but are designated for remedial action under FUSRAP.

In June 1990, DOE and EPA signed a Federal Facility Agreement (FFA) addressing the St. Louis site. This agreement was established to define implementation and oversight roles for the respective agencies involved and to establish an enforceable schedule for completing remedy selection measures for the St. Louis site. In general, DOE, per the FFA, was to develop the documents in consultation with the EPA. Although requested to participate, the State of Missouri elected to not be a party to this agreement.

Under CERCLA, sites are evaluated using a detailed, phased study called a Remedial Investigation/Feasibility Study (RI/FS). This Feasibility Study (FS) evaluates the alternatives for remedial action at the downtown locations. The evaluation of alternatives is based on historical data and the results of the remedial investigation (RI) that present information on the nature and extent



Source: Modified from BNI 1991

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Figure 1-1. Locations of FUSRAP Properties in the St. Louis, Missouri Area

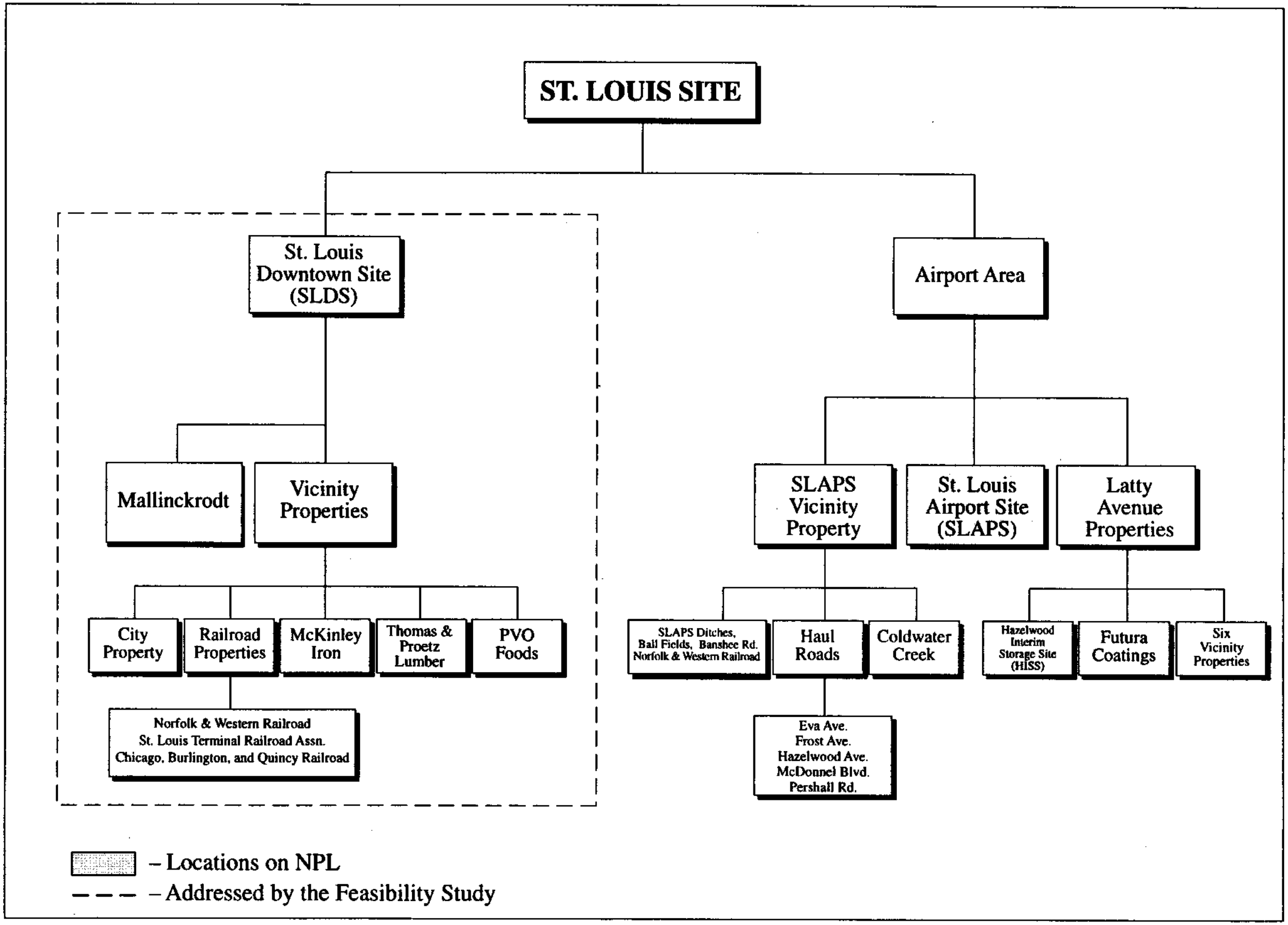

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Figure 1-2. Schematic Representation of the St. Louis Site of contamination, and the baseline risk assessment (BRA) that evaluates potential health and ecological risks if no remedial action is taken at the site.

The RI report (BNI 1994a) summarizes the data and analytical results from radiological and chemical characterization surveys and field investigations conducted at the St. Louis site from 1982 through 1991. These studies were undertaken to determine the nature and extent of contamination and to characterize the geological and hydrogeological features of the properties. In general, the results from the RI indicate that the highest levels of radioactive contamination are at SLDS, SLAPS, and HISS, and the principal radioactive contaminants are isotopes of radium (Ra-226), thorium (Th-230 and Th-232), uranium (U-234, U-235 and U-238), and their radioactive decay products including actinium-227 (Ac-227) and protactinium-231 (Pa-231). The vicinity properties, which were not directly associated with uranium processing or waste storage, exhibit less contamination, primarily from Th-230. Additional characterization data collected after 1991 has been added to the data base and the results are published in the RI addendum (SAIC 1995).

Using site characterization data from the RI, the BRA report (ANL 1993) evaluated the risk for both current and hypothetical future users of the St. Louis site properties. Potential carcinogenic and noncarcinogenic risks to human health and the environment were quantified and compared to determine if risks associated with the site were within acceptable ranges. On the basis of conservative estimates of carcinogenic risk levels, several properties were identified as having cancer risk in excess of the EPA target level under the most stringent future use conditions (residential). Residential use is unlikely for this site, as it has been industrial for over 100 years. A construction worker at SLDS was also found to have an unacceptably high risk. Based on these BRA risk results, remedial action would appear to be warranted.

The RI, BRA, and FS comprise the primary evaluation documents for the CERCLA process. A Proposed Plan (PP) is published separately, but is considered an integral part of the documentation. The PP highlights information from the FS and identifies the preferred alternative. It is the fourth major document of the CERCLA process. The CERCLA process will, after appropriate agency (ie, EPA and state) review and public participation, conclude with the issuance of a Record of Decision (ROD) that will identify the selected remedy for SLDS.

Comments on the remedial alternatives evaluated in this FS and on the preferred alternative identified in the PP will be accepted for 30 days following issuance of the draft FS/PP. CERCLA requires a 30 day review period. A public meeting will be held during the comment period to receive any oral comments the public wishes to make, or receive any written comments the public wishes to submit, regarding any aspect of the draft FS or PP. Responses to public comments on the draft FS and PP will be presented in a response-to-comments document. The response-to-comments document will be appended to the ROD. Remedial decisions made for SLDS on the basis of the final FS/PP will be presented in the ROD.

1.2 PURPOSE AND SCOPE OF REPORT

This FS report identifies, develops, and evaluates remedial action alternatives for SLDS accessible soils, buildings and structures, and groundwater using data from the RI and the BRA. The primary remedial action objective for SLDS is to minimize threats to human health and the environment by eliminating, reducing, or otherwise mitigating the potential hazards posed by site-related contamination. This report also evaluates the potential environmental consequences of the various remedial actions.

Inaccessible soils are contaminated soils that are located beneath buildings and other permanent structures such as railroads. Remediation of inaccessible soils at this time would result in severe economic dislocations because the overlying structures are active industrial, commercial, or railroad facilities. The inaccessible soils will be addressed at a later date when an appropriate remedy that minimizes disruption of active facilities has been identified.

USACE will follow the RI/FS process developed by EPA for environmental compliance under CERCLA (EPA 1988a). The remedial action selected should also comply with all applicable or relevant and appropriate federal and state regulatory requirements. The FS process under CERCLA is conducted in three phases (EPA 1988a):

- developing remedial action objectives, identifying and screening remedial technologies, and formulating potential remedial action alternatives using appropriate technologies;
- screening potential remedial alternatives; and
- conducting detailed analyses of retained remedial alternatives.

1.3 ORGANIZATION OF REPORT

This FS report for SLDS is organized in accordance with guidance from EPA provided for remedial response actions under CERCLA. Section 1 defines the proposed action and includes the introduction, purpose and scope, organization, and summary of consultations with other agencies. Section 2 of this report describes SLDS, its history, the affected environment, and the nature and extent of contamination and summarizes the findings of the BRA. Section 3 defines and screens remedial action objectives and goals and lists retained remedial technologies identified in the Initial Screening of Alternatives (ISA) report (SAIC 1992). Section 4 develops, screens, and evaluates remedial action alternatives for remedial units and combines them into the site-wide alternatives. Section 5 presents a detailed analysis of potential remedial alternatives using CERCLA guidance. Section 5 also provides a comparative analysis of the alternatives for remediation of SLDS. Section 6 contains report references. Applicable or relevant and appropriate requirements (ARARs), cost, and risk analyses are contained in Appendices A through C, respectively.

1.4 CONSULTATION AND COORDINATION WITH OTHER AGENCIES

EPA Region VII and USACE share the lead agency responsibilities for remedial action at the St. Louis MED/AEC sites. An FFA has been negotiated under CERCLA Section 120. Plans and activities at the site are being overseen by EPA Region VII. Plans and activities are also being coordinated with appropriate Missouri state agencies, including the Missouri Department of Natural Resources (MDNR). The identification of federal and state regulations that may impact site remediation is being coordinated with EPA Region VII and MDNR, respectively. Federal and state legislators, local and county officials, and the general public are encouraged to participate in the decision-making processes for SLDS.

The agencies responsible for natural or cultural resources addressed in the RI/FS have been consulted during past St. Louis projects. These include the Missouri State Historic Preservation Office (SHPO), the U.S. Fish and Wildlife Service (FWS), USACE, and Native American Indian county and municipal agencies.

Copies of the administrative record for actions at the St. Louis site are available to the public through the St. Louis Public Library-Cental Library, the St. Louis County Public Library-Prairie Commons Branch, and the USACE Public Information Office at HISS. A community relations program is in place to inform the public of activities at the St. Louis site. This program enables USACE to interact with the public by means of news releases, public meetings, discussions with local interest groups, and communications with interested organizations and individuals.

2. SITE CHARACTERIZATION

2.1 SITE DESCRIPTION AND HISTORY

The St Louis Downtown Site is located in an industrial area on the eastern border of St. Louis, 18 km (11 mi) southeast of the airport area. SLDS consists of the Mallinckrodt Inc. property and adjacent commercial and city owned properties, collectively referred to as the vicinity properties. Mallinckrodt Inc. is 90 m (300 ft) west of the Mississippi River, covers approximately 18 ha (45 acres), and contains many buildings that house Mallinckrodt Inc. offices and non-MED/AEC related chemical processing operations (Figure 2-1). Mallinckrodt Inc. has used, blended, and/or manufactured chemicals at this facility including organics (eg, 1,2-dichloropropane, dichloromethane, phenol, zinc phenolsulfonate, toluene, hexane, dimethylaniline, chloroform, alcohols, propanediols, nitrobenzene, nitrophenols, xylenes, trichloroethylene, hexachlorobutadiene, oxydianiline tars, stearates, biphenyls, acetonitrile) and inorganics (eg, aluminum chloride, hydroxide salts, zinc, sulfuric acid, nitric acid, hydrochloric acid, chromium, sodium iodide, magnesium salts, palladium, bismuth oxychloride). A number of chemicals and compounds that may have been associated with Mallinckrodt operations have been detected in soil and groundwater. A levee/floodwall located to the east of SLDS, protects the area from flood waters.

The Mallinckrodt Inc. facility is bordered by a large metals recycling company (McKinley Iron Works) to the north; the Mississippi River, a defunct food processing company (PVO Foods) and City of St. Louis property to the east; a large lumber yard (Thomas and Proetz Lumber) to the south; and North Broadway and small businesses to the west. Additionally, the Norfolk and Western Railroad (now Norfolk Southern), the Chicago, Burlington, and Quincy Railroad (now Burlington Northern and Santa Fe), and the St. Louis Terminal Railroad Association have active rail lines passing in a north/south direction throughout the facility. These businesses and railroads make up the vicinity properties. An extensive network of utility lines across the site includes underground sewer, sprinkler, water, and natural gas lines, overhead electricity and telephone lines, and plant process pipes. Some of the sewers and subsurface utilities (eg, electricity) are owned by municipal or public utility companies. Runoff from the property is directed to a sewer system that discharges to a publicly owned treatment works which discharges to the river.

G. Mallinckrodt and Company, Manufacturing Chemists, was founded in 1867 by three brothers, Gustav, Edward, and Otto Mallinckrodt, on a portion of their father's land at the corner of Mallinckrodt and Second streets. The original plant, consisting of a stone building, an acid house, and a wooden shed, produced anhydrous ammonia, nitrous ether, acetic and carbolic acids, chloroform, and burnt alum. By 1896, the company had grown to include 50 brick buildings extending from one to seven stories occupying the area now known as Plant 1. The company expanded into manufacture of chemicals for producing dry plates for the fledgling field of photography, morphine, codeine, hydrogen peroxide, and tannic, gallic and pyrogallic acids. The firm was incorporated as Mallinckrodt Chemical Works in 1882.

Edward Mallinckrodt's son, Edward Jr., joined the family business in 1901 after graduating from Harvard University. As a result of his interest in research, such products as a pure and stable

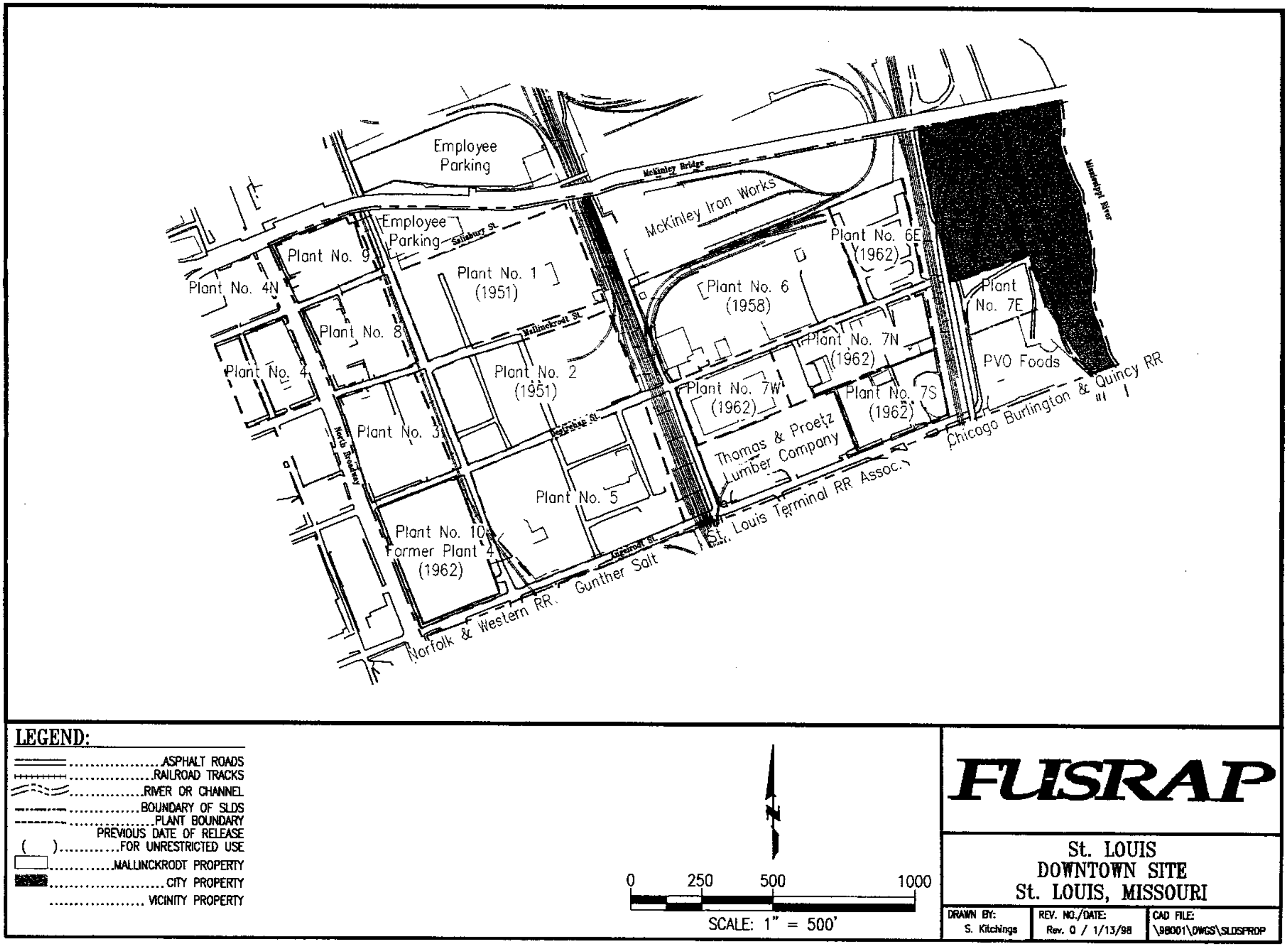

Figure 2-1. Plan View of the St. Louis Downtown Site

ether, analytical reagents to test the purity of chemicals, iodeikon (the first x-ray contrast medium for viewing the gall bladder), and phenobarbital were developed and manufactured between 1914 and 1920s (Historic American Buildings Survey 1997).

Mallinckrodt Chemical Works was contracted by the MED and AEC from 1942 until 1957, to process uranium ore for the production of uranium metal. The process involved the digestion of uranium ore using nitric acid. Residuals of the process, including spent ore, process chemicals and radium, thorium, and uranium, were inadvertently released into the environment through handling and disposal practices. Residuals from the process had elevated levels of radioactive radium, thorium, and uranium. From 1942 to 1945, Plants 1, 2, and 4 (now Plant 10) developed uranium-processing techniques, produced uranium compounds and metal, and recovered uranium metal from residues and scrap. Mallinckrodt, under contract to AEC, decontaminated Plants 1 and 2 from 1948 through 1950 to meet the AEC criteria then in effect, and the AEC released the plants for use without radiological restrictions in 1951.

Starting in 1946, the newly constructed Plant 6 produced uranium dioxide from pitchblende ore. Uranium ore was digested in acid and filtered to form uranyl nitrate, which was extracted and denitrated to produce uranium oxide. Hydrofluoric acid was used to fluorinate the uranium oxide to create uranium tetrafluoride (green salt). The green salt was combined with magnesium and heated to produce uranium metal and magnesium fluoride.

During 1950 and 1951, Plant 4 (now Plant 10) was modified and used as a metallurgical pilot plant for processing uranium metal until it was closed in 1956. During this period, operations began at Plants 6E, 7, 7E, 7N, and 7S. AEC operations in Plant 6E ended in 1957. AEC managed decontamination efforts (removal of radiologically contaminated buildings, equipment, and soil disposed off-site) in Plants 4 and 6E to meet AEC criteria in effect at that time and returned the plants to Mallinckrodt in 1962 for use without radiological restrictions. Since 1962, some buildings have been razed, and new buildings have been constructed at Plants 4 and 6. Plant 7, used to produce green salt, was also used to store reactor cores and to remove metallic uranium from slag by a wet grinding mill/flotation process (Mason 1977). Following decontamination to meet AEC criteria, Plant 7 was released for use with no radiological restrictions in 1962. Plant 7 is currently used primarily for material storage. The company's name was changed to Mallinckrodt, Inc. in 1974.

In 1977, a radiological survey conducted at SLDS found that alpha and beta-gamma contamination levels exceeded guidelines for release of the property for use without radiological restrictions (ORNL 1981). Elevated gamma radiation levels were measured at some outdoor locations and in some of the buildings formerly used to process uranium ore. Ra-226 concentrations as high as 2,700 picoCuries per gram (pCi/g) above background and U-238 concentrations as high as 20,000 pCi/g above background were found in subsurface soil. Additionally, radon and radon daughter concentrations in two buildings exceed guidelines for nonoccupational radiation exposure. In response to this survey, an RI was conducted to characterize the nature and extent of contamination (BNI 1994a).

southwest of the southwestern corner of SLDS (City of St. Louis Community Development Agency 1992).

SLDS is zoned "K" (unrestricted district) by the City of St. Louis. This industrial zone allows all uses except residential, provided that no other city codes are violated. Some uses allowed within this zone under conditional use permit are acid manufacture, petroleum refining, and stockyards (Zoning Code, City of St. Louis, Section 26.60). The long-term plans for this area are to retain the industrial uses, encourage the wholesale produce district, and phase out any junk yards, truck storage lots, and the remaining, marginal residential uses (personal communication, City of St. Louis Community Development Agency 1992).

2.2.2 Climatology, Meteorology, and Air Quality

Climatological and meteorological conditions in a region greatly influence the relationship between air pollutant emissions and ambient air quality in the area. The climate of the St. Louis area is characterized as warm and moist in summer and cold and dry in winter (Muller and Oberlander 1978). The region is dominated by warm, moist maritime tropical air masses, which flow northward from the Gulf of Mexico region, and by colder, drier polar air masses, which drift to the southeast from the Canadian Provinces. Climatological and meteorological data from the Lambert-St. Louis International Airport over a 30-year period are summarized in Table 2-1.

In general, southerly and northwesterly winds dominate the wind regime of the St. Louis region. Southerly winds predominate from May through November, and northwesterly winds predominate from December through April. The annual wind speed and wind direction is shown on Figure 2-3. Annual normal high and low temperatures are 31°C and -5°C (88°F and 23°F), respectively. The area averages 91 cm (36 in) per year in total water equivalent precipitation (ie, rainfall plus water content of melted snowfall). Average annual snowfall is roughly 66 cm (26 in).

The tornado is the most common form of severe weather observed in this region. From 1916 through 1985, 52 recorded tornadoes occurred in the St. Louis metropolitan area. In 1990, Missouri had 31 storms in 14 storm days, most of them in May and June. Based on the record between 1953 and 1990, Missouri is ranked seventh nationally in the occurrence of tornadoes and averages 11 tornado and 27 storm days per year (NOAA 1990).

Tropical hurricanes, storms, and disturbances are much less frequent than tornadoes. Between 1886 and 1986, only eight tropical storms have crossed within a 2 × 2 degree box centered on the St. Louis area (Tropical Cyclone Data Tape-TD9267). The consequences of such storms in the St. Louis area result in heavy rains and flooding rather than destructive winds.

Ambient air quality and the conditions for air emission control are at their worst on summer mornings in the St. Louis area because of the pattern of strong temperature inversions at night. This results from atmospheric stability and the low mixing height. The mixing height is the depth of the atmosphere over which a pollutant release will be effectively dispersed. Thus, relatively low mixing heights give rise to higher surface level concentrations due to reduced vertical mixing.

Table 2-1. Climatological and Meteorological Conditions - St. Louis, Missouri

	Temperature (°F)						
	Normal			Extreme			
Month	Max	Min	Avg	High	Year	Low	Year
January	39.9	22.6	31.6	76	1970	-14	1977
February	44.2	26.0	35.1	85	1972	-10	1979
March	53.0	33.5	43.3	88	1963	-5	1960
April	67.0	46.0	56.5	92	1970	22	1975
May	76.0	55.5	65.8	92	1978	31	1976
June	84.9	64.8	74.9	98	1971	43	1969
July	88.4	68.8	78.6	107	1980	51	1972
August	87.2	67.1	77.2	105	1980	47	1965
September	80.1	59.1	69.6	100	1971	36	1974
October	69.8	48.4	59.1	94	1963	23	1976
November	54.1	34.9	45.0	82	1978	1	1964
December	42.7	26.5	34.6	76	1970	-10	1976
Annual	88.4	22.6	55.9	107	1980	-14	1977

Month	**Precipitation (in)**			**Relative Humidity (%)**				**Wind**	
	Max	**Min**	**Avg**	**12 am**	**6 am**	**12 n**	**6 pm**	**Speed (mph)**	**Dir**
January	5.38	0.22	1.85	78	83	66	71	10.4	NW
February	4.17	0.25	2.06	78	82	63	66	10.9	NW
March	6.67	1.09	3.03	75	82	59	60	11.9	WNW
April	9.09	0.99	3.92	71	79	55	53	11.5	WNW
May	7.25	1.02	3.86	76	83	56	56	9.4	S
June	8.65	0.47	4.42	78	84	56	55	8.8	S
July	10.71	0.60	3.69	78	86	57	56	7.9	S
August	6.44	0.08	2.87	81	89	57	58	7.6	S
September	6.24	trace	2.89	82	91	59	61	7.9	S
October	5.77	0.21	2.79	77	86	55	60	8.7	S
November	5.74	0.44	2.47	78	85	63	68	9.9	S
December	6.50	0.32	2.04	81	85	69	74	10.3	WNW
Annual	10.71	0.08	2.99	78	84	60	62	9.6	S

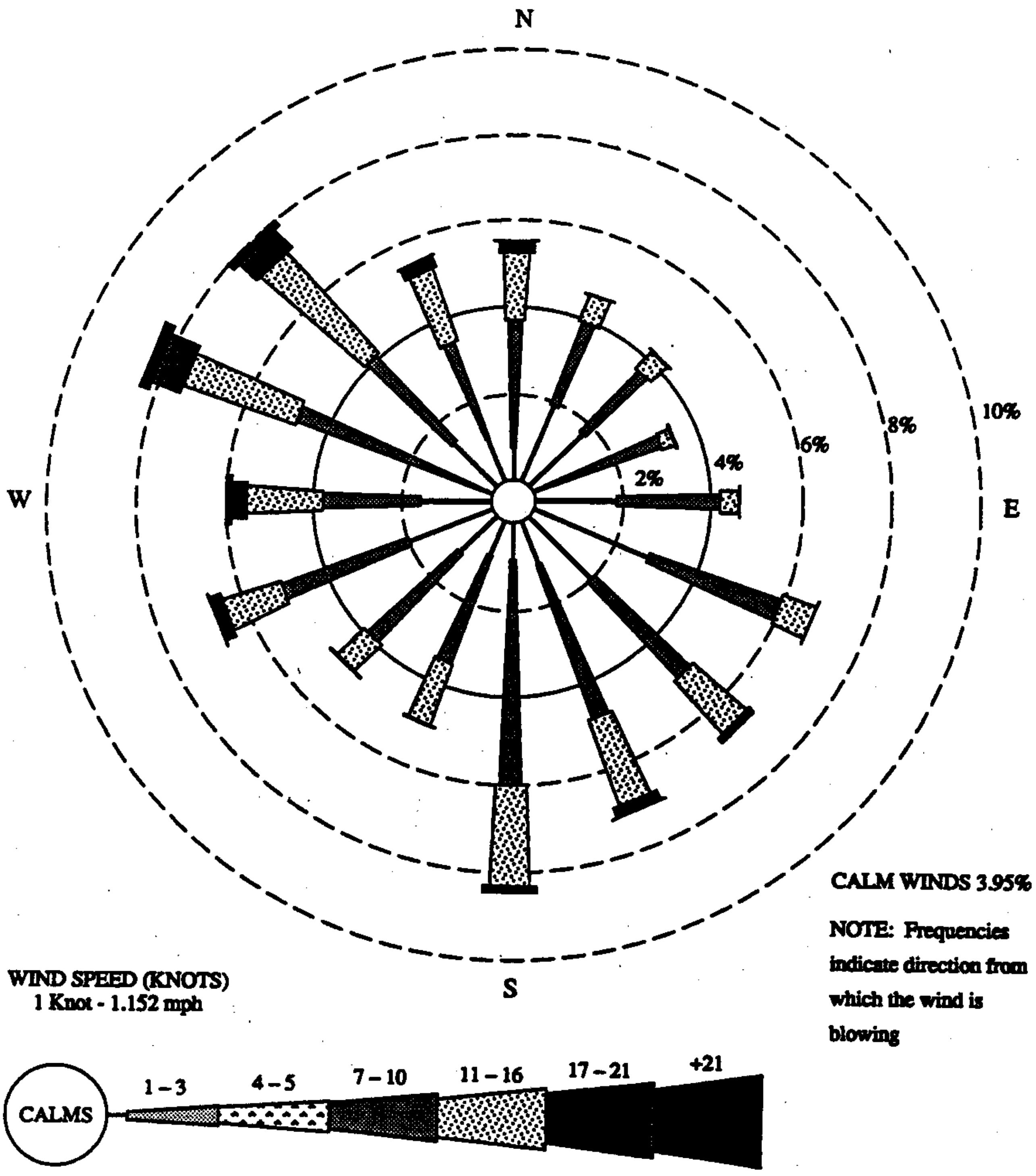

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Figure 2-3. Annual Wind Rose for Lambert St. Louis International Airport, Station 13994 (generated from National Weather Service data, 1989)

The ambient air quality for the St. Louis city/county region, monitored at five sites equally distributed between the downtown and airport areas, does not exceed the 24- or 3-hour ambient standards (365 and 1,300 $\mu g/m^3$, respectively) for particulates in the city. Most particulates result from the dust and smoke from highway traffic, commercial and domestic fuel combustion, and construction activities. The particulate levels within this area are marginally acceptable (O'Donnell 1981).

The criteria pollutants—carbon monoxide, sulfur dioxide, and nitrogen oxides—are within ambient standards; ozone levels [0.135 parts per million (ppm)] exceed the hourly standard (0.125 ppm) at only one location in St. Louis County, a result attributed to hydrocarbon emissions (O'Donnell 1981).

2.2.3 Geology and Soils

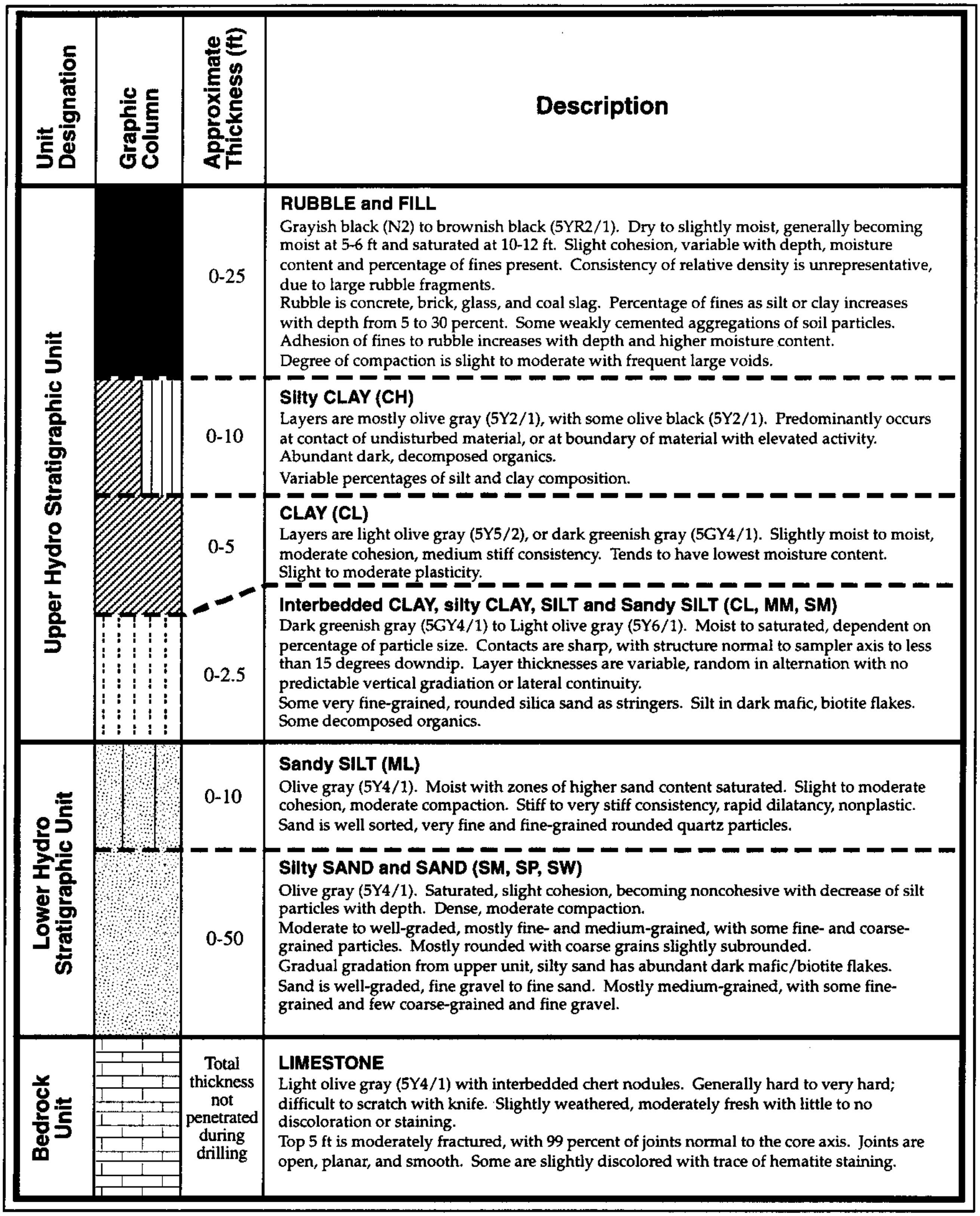
The St. Louis area is located within a stable geologic province. The geologic history is characterized by the cyclic deposition of 1,800 m (6,000 ft) of Paleozoic sandstones, shales, limestones, and dolomites. These layers thicken into the Illinois Basin east of the study area and toward the Ozark Dome southwest of the study area. They are nearly horizontal, dipping less than 1 degree to the northeast as a result of uplift of the Ozark Dome.

St. Louis is located in a tectonically inactive region but it is approximately 240 km (150 mi) from the tectonically active New Madrid seismic zone. A search of reported seismic events from 1795 to 1984 indicated 31 events of intensity III through VII on the Modified Mercalli intensity (MMI) scale within a 48-km (30-mi) radius around St. Louis (Weston 1979, BNI 1994a). An earthquake of local intensity VII may cause damage to structures, but no surface fault rupture in the St. Louis area would be exhibited (Weston 1979).

The stratigraphic section of interest to St. Louis consists of the Pennsylvanian and Mississippianbedrock and the overlying Pleistocene and recent nonlithified sediments. The surficial sediments consist of sand, silt, and clay that typically range from less than 1.5 m (5 ft) to more than 30 m (100 ft) thick. These nonlithified deposits originated from multiple sources: glacial outwash consisting of mixtures of clay, silt, sand, and gravel; silts and clays deposited in glacial lakes; wind-deposited loess; and deposits from the Mississippi and Missouri rivers.

The downtown area stratigraphy (Figure 2-4) is characterized by a fill layer present over most of the property with an average thickness of 4 m (13 ft). The fill present at most locations consists of unconsolidated brick, reinforced concrete, organic material, coal slag with minor sand, coal ash, coal cinders and silt as the matrix. Two nonlithified hydrostratigraphic units were distinguished based on a difference in geologic properties.

The upper hydrostratigraphic unit consists of fill and laterally discontinuous silty clay with interbedded silty clay, clay, silt, and sandy silt, and varies in thickness from 3 to 20 m (10 to 65 ft). The lower nonlithified unit is a sandy silt and silty sand that grades into sand east toward the Mississippi River (BNI 1994a).



Unit Designation	Graphic Column	Approximate Thickness (ft)	Description
Upper Hydro Stratigraphic Unit		0-25	**RUBBLE and FILL** Grayish black (N2) to brownish black (5YR2/1). Dry to slightly moist, generally becoming moist at 5-6 ft and saturated at 10-12 ft. Slight cohesion, variable with depth, moisture content and percentage of fines present. Consistency of relative density is unrepresentative, due to large rubble fragments. Rubble is concrete, brick, glass, and coal slag. Percentage of fines as silt or clay increases with depth from 5 to 30 percent. Some weakly cemented aggregations of soil particles. Adhesion of fines to rubble increases with depth and higher moisture content. Degree of compaction is slight to moderate with frequent large voids.
		0-10	**Silty CLAY (CH)** Layers are mostly olive gray (5Y2/1), with some olive black (5Y2/1). Predominantly occurs at contact of undisturbed material, or at boundary of material with elevated activity. Abundant dark, decomposed organics. Variable percentages of silt and clay composition.
		0-5	**CLAY (CL)** Layers are light olive gray (5Y5/2), or dark greenish gray (5GY4/1). Slightly moist to moist, moderate cohesion, medium stiff consistency. Tends to have lowest moisture content. Slight to moderate plasticity.
		0-2.5	**Interbedded CLAY, silty CLAY, SILT and Sandy SILT (CL, MM, SM)** Dark greenish gray (5GY4/1) to Light olive gray (5Y6/1). Moist to saturated, dependent on percentage of particle size. Contacts are sharp, with structure normal to sampler axis to less than 15 degrees downdip. Layer thicknesses are variable, random in alternation with no predictable vertical gradiation or lateral continuity. Some very fine-grained, rounded silica sand as stringers. Silt in dark mafic, biotite flakes. Some decomposed organics.
Lower Hydro Stratigraphic Unit		0-10	**Sandy SILT (ML)** Olive gray (5Y4/1). Moist with zones of higher sand content saturated. Slight to moderate cohesion, moderate compaction. Stiff to very stiff consistency, rapid dilatancy, nonplastic. Sand is well sorted, very fine and fine-grained rounded quartz particles.
		0-50	**Silty SAND and SAND (SM, SP, SW)** Olive gray (5Y4/1). Saturated, slight cohesion, becoming noncohesive with decrease of silt particles with depth. Dense, moderate compaction. Moderate to well-graded, mostly fine- and medium-grained, with some fine- and coarse-grained particles. Mostly rounded with coarse grains slightly subrounded. Gradual gradation from upper unit, silty sand has abundant dark mafic/biotite flakes. Sand is well-graded, fine gravel to fine sand. Mostly medium-grained, with some fine-grained and few coarse-grained and fine gravel.
Bedrock Unit		Total thickness not penetrated during drilling	**LIMESTONE** Light olive gray (5Y4/1) with interbedded chert nodules. Generally hard to very hard; difficult to scratch with knife. Slightly weathered, moderately fresh with little to no discoloration or staining. Top 5 ft is moderately fractured, with 99 percent of joints normal to the core axis. Joints are open, planar, and smooth. Some are slightly discolored with trace of hematite staining.

Note: The codes in parentheses following lithologies are the Unified Soil Classification Systems codes.

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Source: Modified from BNI 1992

Figure 2-4. Generalized Stratigraphic Column for the Downtown Area

Limestone bedrock underlies the nonlithified sediments at a depth ranging from 6 m (19 ft) on the western side of SLDS to 24 m (80 ft) near the Mississippi River. Bedrock underlying SLDS is limestone with some interbedded chert nodules. The top 1.5 m (5 ft) of the bedrock is moderately fractured with joints oriented horizontally. No confining layer occurs between the bedrock and overlying sand. Groundwater discharges from the bedrock directly into the river or into the overlying sediments and then to the Mississippi River.

2.2.4 Water Resources

2.2.4.1 Surface Water

SLDS is located at Mississippi River Mile 182.5 on the western bank of the Mississippi (Figure 2-1), 20 km (12.7 mi) downstream from the confluence of the Mississippi (River Mile 195.2) and Missouri (River Mile 0) Rivers. SLDS runoff flows into the Mississippi River through St. Louis municipal stormwater underground drainage system. All metropolitan municipal water intakes are located upstream from this area, except the Illinois-American Water Plant (Figure 1-1). This downstream intake on the east bank of the Mississippi River is 12 km (7.5 mi) downstream. It supplies a small percentage of the water required by the City of East St. Louis. The major surface water bodies in the area are the Mississippi, Missouri and Meramac Rivers, which supply 97 percent of the 4.5 billion liters (1.2 billion gallons) per year of drinking and industrial water for the St. Louis area (Miller 1974).

The Mississippi River in the St. Louis area is classified as a Class "P" (permanent flow) waterway (Ford 1992). It is protected for the following water uses: irrigation, livestock and wildlife watering, aquatic life, boating, drinking water supply, and industrial uses. The water quality of the Mississippi River in this area is fair to good. It meets all of the water quality standards set by the State of Missouri except for chlordane in fish tissue (Ford 1992). For this reason, the State of Missouri has issued a fish advisory. Increased levels of polychlorinated biphenyls (PCBs) present downstream from St. Louis suggest that a significant source of PCBs is present in St. Louis. In addition, high levels of phenolic compounds and bacteria have been detected downstream from St. Louis.

The Mississippi River at the St. Louis gauging station has a drainage area of approximately 1.8×10^6 km^2 (700,000 mi^2). The average flow for a 114-year period is 5×10^6 m^3/s [177,000 cubic feet per second (cfs)]. The minimum flow recorded in this period is 5×10^5 m^3/s (18,000 cfs), and the maximum measured flow is 3×10^7 m^3/s (1,019,000 cfs). Although flooding has occurred every month of the year, higher flows are frequently associated with snow melt and heavy rains in spring. Lowest flows typically occur during December or January. Flooding information above the confluence zone of the Mississippi and Missouri Rivers is shown in Tables 2-2 and 2-3, respectively.

2.2.4.2 Groundwater

Groundwater in the St. Louis area is generally of poor quality with high concentrations of dissolved aluminum, calcium, iron, manganese, and total dissolved solids. The principal aquifers in the St. Louis area are located in the nonlithified alluvial deposits associated with the major river

Table 2-2. Flood Frequency Distribution for the Mississippi River at St. Louis Missouri (1934–1979)

Recurrence Interval (years)	Discharge Level (cfs)	Exceedence Probability
1.01	146,000	0.99
1.05	223,000	0.96
1.11	373,000	0.90
1.25	341,000	0.80
2.00	490,000	0.50
5.00	651,000	0.20
10.0	735,000	0.10
25.0	820,000	0.04
50.0	872,000	0.02
100	915,000	0.01
200	952,000	0.005

Table 2-3. Flood Frequency Distribution for the Missouri River at Hermann, Missouri (1929-1979)

Recurrence Interval (years)	Discharge Level (cfs)	Exceedence Probability
1.01	83,900	0.99
1.05	117,000	0.95
1.11	140,000	0.90
1.25	172,000	0.80
2.00	254,000	0.50
5.00	370,000	0.20
10.0	449,000	0.10
25.0	549,000	0.04
50.0	624,000	0.02
100	699,000	0.01
200	775,000	0.005

system. Aquifers also exist in the bedrock formation underlying the unconsolidated alluvial deposits. Only one to two percent of the water used for all purposes in the St. Louis area comes from groundwater (Miller 1974).

Three distinct hydrologic units underlie the downtown area including a partially saturated to saturated zone of rubble fill and alluvial sediments, a lower nonlithified alluvial unit, and a limestone bedrock unit. Saturated conditions occur in the rubble fill above clayey lenses which are discontinuous across portions of the site. Shallow saturated conditions were encountered in 115 boring locations drilled across SLDS at depths between 1 and 5 m (3 and 17 ft) below ground surface.

The upper hydrostratigraphic unit consists of fill, interbedded silty clay, clay, silt, and sandy silt overlying a wedge of silty sand and sand that thickens toward the Mississippi River (BNI 1994a). The fill averages 3.9 m (13 ft) in thickness and consists of unconsolidated fill including brick, reinforced concrete, and coal slag with sand in a silt matrix. Groundwater flows in both nonlithified hydrostratigraphic units, generally moving east toward the Mississippi River (BNI 1994a). Adjacent to the river channel, potentiometric levels in the lower hydrostratigraphic unit fluctuate in response to the river stage. The hydraulic conductivity of the upper hydrostratigraphic unit was measured to be 1×10^{-5} cm/sec (4×10^{-6} in/sec). Hydraulic conductivity testing was not carried out for the lower nonlithified hydrostratigraphic unit (BNI 1990). The calculated hydraulic gradient in the upper hydrostratigraphic unit is approximately 0.0159 to the east and the calculated gradient in the lower unit is approximately 0.0090 eastward. The hydraulic interconnection between the units has not been established. Wells screened in the relatively fine-grained upper hydrostratigraphic unit have measured water levels that are on the order of 9 m (30 ft) higher than wells monitoring the more permeable lower hydrostratigraphic unit indicating some degree of confinement probably associated with a leaky aquitard.

The nonlithified units overlie limestone bedrock along an erosional contact that dips toward the Mississippi River with a gradient of approximately 0.03. Reported values of hydraulic conductivity for the bedrock surface ranges between 3×10^{-4} cm/sec and 1×10^{-3} cm/sec (1×10^{-4} to 4×10^{-4} in/sec) (BNI 1994a).

An off-site well survey has not been conducted around the Downtown Area. The groundwater systems underlying the SLDS have been monitored historically by nine onsite wells. An additional eight shallow wells (5S, 6S, 7S, 8S, 10S, 11S, 12S, and 13S) were installed and sampled in 1992. All existing wells were sampled again in 1997. Wells 5, 6, 7, and 8 were installed next to already existing deep wells. Four of the wells (W01S, W02S, W03S, W04S) are screened in the upper, fine-grained alluvial unit. Screens in two wells (W01S and W04S) extend into the upper portion of the limestone bedrock on the western edge of the site where the lower hydrostratigraphic unit is not present. The remaining wells are screened in the bottom third of the lower hydrostratigraphic unit above the bedrock. Recharge of the lower hydrostratigraphic unit is estimated to occur from precipitation, upgradient hydrostratigraphic units, from the Mississippi River, artesian flow from the bedrock, and possible leakage from underground utilities. Infiltration of precipitation at the SLDS should be a relatively minor source of recharge at the site because a large portion of the surface area is covered with asphalt and buildings (BNI 1994a). Data from the onsite wells confirms that the groundwater beneath SLDS is of poor quality as in the rest of the area.

2.2.5 Biological Resources

The biological resources description of SLDS reflects reconnaissance conducted during daylight hours (0615 to 1630 hours) on May 14 and 15, 1992, and a literature review (primarily, Orzell 1979, St. Louis County Department of Planning 1986, and Weston 1979).

St. Louis is located in the Oak-Hickory-Bluestem Parkland section of the Prairie Parkland Province (Bailey 1980) and within the Florissant Basin (Lark 1992). Topography is gently rolling with low bluffs north of the Missouri. Presettlement vegetation is characterized by deciduous woodlands intermixed with open prairie (Bailey 1980). The Missouri and Mississippi Rivers are a major influence on the vegetation of the area. Common trees before development included oaks (*Quercus* sp.), hickories (*Carya* sp.), elms (*Ulmus* sp.), sycamores (*Platanus* sp.), cottonwoods (*Populus* sp.), redbuds (*Cercis* sp.), hackberries (*Celtis* sp.), and buckeyes (*Aesculus* sp.) (Bailey 1980). Tall grass prairie species in presettlement times included big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), and prairie junegrass (*Koleria cristata*) (Weston 1979). Today, little presettlement vegetation exists in the area.

The downtown area is completely developed. The highly reworked area is covered with cinder and gravel, and only such hardy vegetation as annual bromegrass (*Bromus* sp.) and mustards (*Lepidium* sp.) survive. Large cottonwoods (*Populus* sp.) and some maples (*Acer* sp.) border the river at the slope. Sumac (*Rhus* sp.) and willow (*Salix* sp.) are understory woody species, and herbaceous understory cover is scant. Part of the flood control levee runs through this area and has been seeded to perennial bromegrass (*Bromus* sp.), American vetch (*Vicia americana*), and yellow sweetclover (*Melilotus officinalis*). Other herbaceous species common onsite include sunflower (*Helianthus* sp.), goldenrod (*Solidago* sp.), ragweed (*Ambrosia* sp.), chickweed (*Stellaria* sp.), thistle (*Cirsium* sp.), dock (*Rumex* sp.), and plantain (*Plantago* sp.).

The only animals observed at SLDS during the site survey were insects (eg ants) and swifts (*Chaetura pelagica*), red-winged blackbirds (*Agelaius tricolor*), and pigeons (*Columba livia*) flying through the area. Waterfowl may overfly the area during migration. Small mammals, particularly house mice (*Mus musculus*) and rats (*Ratus* sp.) have habitat in the area.

2.2.6 Threatened and Endangered Species

The only federal and state designated, endangered, or threatened species that may occur within the area of the proposed action are the pallid sturgeon (*Scaphirhynchus albus)* and bald eagle (*Haliaeetus leucocephalus*). Pallid sturgeon are found in both the Mississippi and Missouri Rivers. Bald eagles are known to stay through the winter in the region. It is doubtful that they use the downtown area because of poor habitat quality (ie, sparse vegetation, significant noise and human activity). No sign of these species or their activities was present at SLDS.

2.2.7 Wetlands and Floodplains

No wetlands in the downtown area have been designated by USACE or the U.S. Fish and Wildlife Service. Portions of the downtown area lie within the 100-year floodplain. At SLDS, the natural drainage has been disrupted by urban development, and the property has been protected from flooding by a series of levees constructed in the 1960s. Storm runoff is controlled by a system of sewers equipped with weirs to direct excess flow to the river. Portions of the city property lie within the 100-year floodplain, 130 m (430 ft) above MSL [U.S. Department of Housing and Urban Development (HUD 1979)]. In the event of a flood, portions of the downtown area city property could be inundated.

2.2.8 Population and Socioeconomics

SLDS is located in an urban setting within the City of St. Louis. Analyses of census and other data for the City of St. Louis are compared to data for the St. Louis Metropolitan Statistical Area (MSA), which includes the City of St. Louis; St. Louis, St. Charles, Franklin, and Jefferson counties in Missouri; and five counties in Illinois.

2.2.8.1 Demographics

Recent trends in population growth and density continue to show decreases in both the City of St. Louis and increases in both for most of the surrounding counties as shown in Tables 2-4 and 2-5. The City of St. Louis, which contains the downtown area, had a 1990 population of 396,685, a decrease of 12.4 percent from 1980. St. Louis County had a 1990 population of 993,529 (EWGCC 1991), an increase of 2.0 percent from 1980. The population data for the period from 1990 to 1992 indicate that the historical trend of decreasing population in the city and increasing population in the county is continuing. The housing trends follow these population trends. Tables 2-5 and 2-6 summarize the population density per land area and the number of dwelling units for the city, the county, and MSA. Table 2-6 reflects the changes in the number of housing units in the city, the county, and the St. Louis MSA. Table 2-7 shows the 1990 housing characteristics for the identified region. The City of St. Louis has 19 percent of the single family units, and 55 percent of the multi-family units in the area. The overall occupancy rate is 85 percent for the City of St. Louis and 95 percent for St. Louis County. The city's average owner vacancy rate is almost double the county's.

SLDS is located within Census Tract 1267, where the residential population was 2,867 in 1990, as shown in Figure 2-5. The total population within 1.6 km (1 mi) of SLDS was 10,054, approximately 2.5 percent of the population of the City of St. Louis. The number of occupied dwellings within the 1.6-km (1-mi) radius is 4,710, with an average occupancy of 2.1 people per dwelling.

2.2.8.2 Socioeconomics

The growth trend of business establishments parallels the demographic trends discussed in Section 2.2.8.1. Baseline data for unemployment trends and the number of business establishments

Table 2-4. Population of the St. Louis Metropolitan Statistical Area

	1950	1960	1970	1980	1990	1992	Percent Change 1980-1990	Percent Change 1990-1992
				Missouri				
St. Louis City	856,796	750,026	622,236	452,804	396,685	387,900	-12.4%	-2.2%
St. Louis County	406,349	703,532	951,671	974,180	993,529	995,900	2.0%	0.2%
St. Charles County	29,382	52,970	92,954	144,107	212,907	221,900	47.7%	4.2%
Jefferson County	38,007	66,377	105,248	146,183	171,380	176,000	17.2%	2.7%
Franklin County	36,046	44,566	55,127	71,233	80,603	82,400	13.2%	2.2%
Missouri Subtotal	1,367,030	1,617,471	1,827,236	1,788,507	1,855,104	1,864,100	3.7%	0.5%
				Illinois				
St. Clair County	205,995	262,509	285,176	267,531	262,852	262,100	-1.7%	-0.3%
Madison County	182,307	224,689	250,934	247,664	249,238	248,900	0.6%	-0.1%
Monroe County	13,282	15,507	18,831	20,117	22,422	22,300	11.5%	-0.5%
Clinton County	22,594	24,029	28,315	32,617	33,944	34,000	4.1%	0.3%
Jersey County	15,264	17,023	18,492	20,538	20,539	20,600	0.0%	0.3%
Illinois Subtotal	439,442	543,757	601,748	588,467	588,995	587,900	0.1%	-0.2%
Metropolitan Statistical Area	1,806,472	2,161,228	2,428,984	2,376,974	2,444,099	2,452,000	2.8%	0.3%

Source: EWGCC 1991

Table 2-5. Total Population and Population Density for the St. Louis Region, 1980–1990

Region	1980 population	1990 population	1990 Land Area		1990 persons per	
			km²	mi²	km²	mi²
City of St. Louis	452,804	396,685	61	159	2,501	6,503
St. Louis County	974,180	993,529	506	1,316	755	1,964
Regional MSA	2,376,968	2,444,099	5,341	13,887	176	458

Source: EWGCC 1991

Table 2-6. Housing Units in the St. Louis Region, 1980–1990

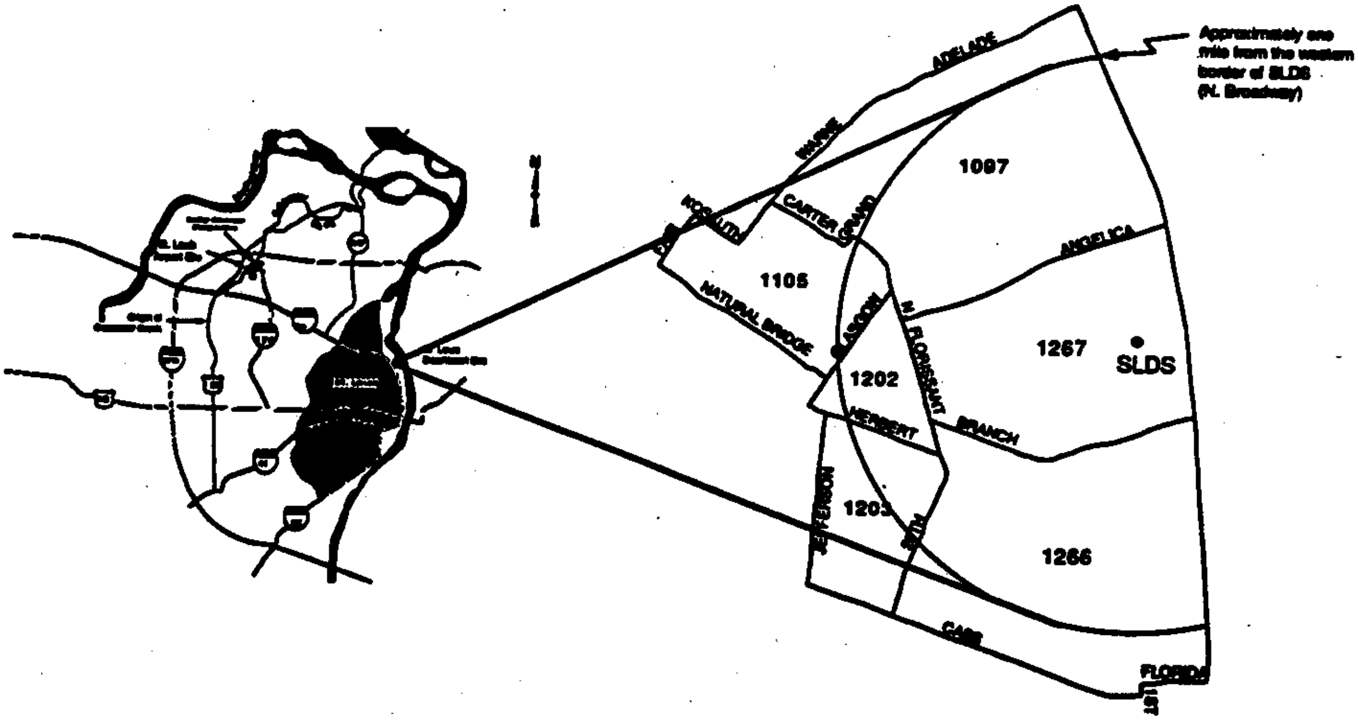
Area	Total Housing Units 1980	Total Housing Units 1990	% change 1980–1990
City of St. Louis	202,113	194,919	-0.3
St. Louis County	358,040	401,839	1.1
Regional MSA	887,425	991,000	1.5

Source: EWGCC 1991

Table 2-7. Housing Characteristics 1990

	City of St. Louis	St. Louis County
Single Family Units	71,809	302,271
Multi-family Units	121,752	98,345
Mobile Homes	2,078	
Total Housing Units	194,919	401,839
Total Occupied Units	164,931	380,110
Average Number Persons per Unit	2.34	2.57
Renter Vacancy Rate	13.2	9.4

Source: BEA 1991, RCGA 1992



Approximately one mile from the western border of SLDS (N. Broadway)

Census Tract	1-Mile Pop.[b]	Dwelling Units[b,c]	Mean Pop./Unit	Population Ages[d]		
				0-18	19-49	50 & Over
City of St. Louis	396,685	164,931	2.4	105,455	172,263	115,312
1267 (SLDS)	2,867	1,068	2.7	1,135	1,207	506
1097	1,745	879	2.0	2,450	2,322	1,211
1105	585	291	2.0	1,092	1,191	703
1202	1,745	713	2.4	696	699	465
1203	980	471	2.1	865	1,011	502
1266	2,132	1,288	1.7	1,565	1,466	742
Total (Census Tract)	10,504[d]	4,710[d]	2.2	7,803	7,896	4,129

[a] Source: U.S. Census Bureau 1990.

[b] Population and dwelling units within 1.6 km (1 mi) of SLDS.

[c] Figures reported represent the total number of occupied dwelling units.

[d] Figures represent population living within the entire census tract.

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Figure 2-5. Census Tracts within 1.6 km (1 mi) of SLDS

Table 2-8. Comparison of Unemployment Rates in the St. Louis Region, 1980–1991[a]

Year	St. Louis City (Annual, %)	St. Louis County (Annual, %)
1980	8.6	6.4
1981	9.5	6.6
1982	10.5	7.8
1983	12.5	8.6
1984	9.7	6.1
1985	9.8	5.0
1986	9.3	4.7
1987	9.3	4.6
1988	8.8	4.0
1989	8.1	3.8
1990	8.2	4.3
1991	9.0	5.1

[a] Source: Missouri Division of Employment Security 1992.

Table 2-9. Number of Business Establishments in the St. Louis Region, 1983-1989[a]

Region	1983	1985	1987	1989	% Change 1983-1989
St. Louis City	10,541	10,267	10,283	10,008	-0.05
St. Louis County	24,535	26,533	27,917	29,145	19

[a] Source: Metro Trends, Missouri State Census Data Center 1990.

from 1980 to 1991 in the city and county. Table 2-9 summarizes the percent change in the number of business establishments in the city and the county. A total of 325,000 people were employed in the City of St. Louis in 1989, 85 percent in the private sector and 15 percent in government. The distribution of employment by sector is shown in Table 2-10. Since 1980, the three biggest employment sectors in the city have been the services industry, manufacturing, and government, but employment has declined in all three. The greatest annual average growth in employment from 1980–1989 occurred in the small agricultural services, mining, and the military employment sectors. Table 2-11 shows the breakdown in earnings by sector. The industry sectors with the largest earnings include manufacturing, services, and government. The greatest annual average growth in earnings from 1980 to 1989 occurred in agricultural services, the military, and the services industry. Businesses employing more than 50 people within a 1.6-km (1-mi) radius of the downtown site are shown on Figure 2-6. Table 2-12 shows per capita income trends for the city and compares these trends with average earnings for the construction and services sectors, which probably will be most affected by the proposed remedial activities at the downtown site (BEA 1991). This table indicates that inflation adjusted per capita income and service industry earnings have grown 2 and 8 percent, respectively. The construction industry earnings in St. Louis, when adjusted for inflation, have declined 12 percent from 1980 to 1989.

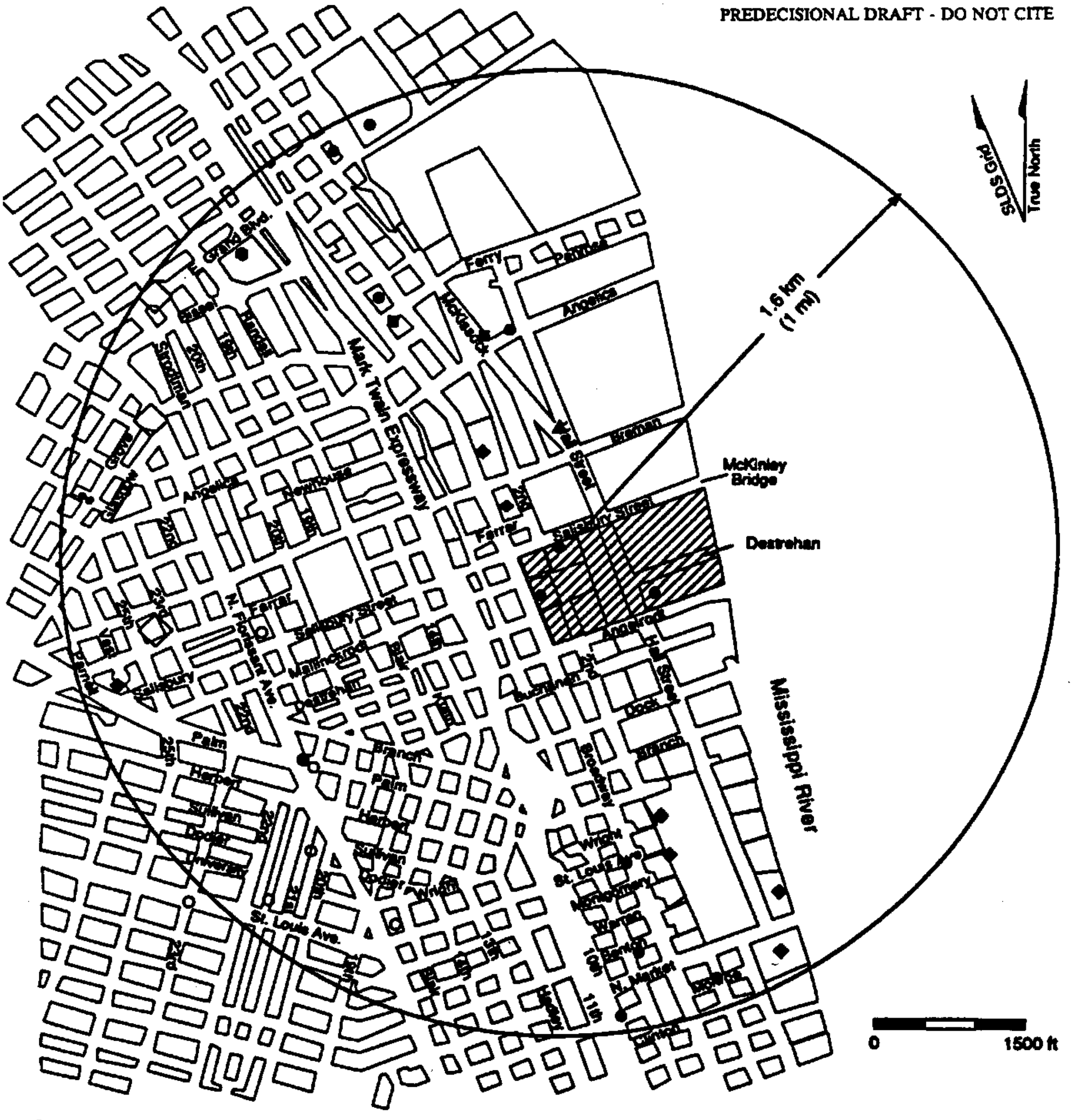
Table 2-10. Distribution of City of St. Louis Employment, 1980-1989[a]

Employment Sector	Number of People Employed			Average Annual Growth 1980-1989
	1980	1985	1989	
Agriculture Services	243	370	529	8.0%
Mining	250	664	298	1.7%
Construction	11,003	10,719	10,461	-0.5%
Manufacturing	89,323	62,731	49,818	-6.0%
Transportation and Public Utilities	32,904	26,041	26,529	-2.2%
Wholesale Trade	31,016	23,295	21,515	-3.7%
Retail Trade	38,408	37,942	37,964	-0.1%
Finance, Insurance, and Real Estate	31,658	28,947	27,356	-1.5%
Services	113,938	88,129	99,092	-1.4%
Government and Government Enterprises	56,670	55,282	50,897	-1.0%
Federal, Civilian	24,434	23,810	22,620	-0.7%
Military	3,548	4,482	4,258	1.8%
State and Local	28,688	26,990	24,019	-1.8%

Table 2-11. Distribution of City of St. Louis Employment Earnings, 1980-1989[a]

Employment Sector	Earnings by Industry Sector (thousands)			Average Annual Growth 1980-1989
	1980	1985	1989	
Agriculture Services	2,547	4,735	9,053	13.5%
Mining	31,366	59,622	27,473	-1.3%
Construction	252,766	324,064	338,661	2.9%
Manufacturing	1,890,386	1,899,464	1,755,389	-0.7%
Transportation and Public Utilities	846,457	921,925	1,065,666	2.3%
Wholesale Trade	631,877	635,819	709,188	1.2%
Retail Trade	369,112	490,482	549,791	4.0%
Finance, Insurance, and Real Estate	470,945	589,118	730,357	4.5%
Services	1,403,345	1,735,216	2,311,241	5.1%
Government and Government Enterprises	938,148	1,296,480	1,408,834	4.1%
Federal, Civilian	487,981	672,346	724,206	4.0%
Military	40,052	68,989	73,500	6.3%
State and Local	410,115	555,145	611,128	4.1%

[a] Source: Regional Economic Information System, Bureau of Economic Analysis, April 1991.



Source: St. Louis Community Development Agency 1992

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KEY

▨	SLDS and Vicinity Properties	⬢	Services
●	Manufacturing	■	Construction
◆	Wholesale Trade	▲	Transportation

Figure 2-6. Businesses Employing More than 50 People within 1.6-km (1-mi) Radius of SLDS

Table 2-12. Trends in Per Capita Income and Earnings of Selected Industries for the City of St. Louis, 1980–89[a]

Year	Per Capita Income (thousands)	Real Per Capita Income[b] (1987 = 100)	Average Earnings (thousands)		Real Average Earnings[b] (thousands)	
			Construction	Services	Construction (1987 = 100)	Services (1987 = 100)
1980	9,453	13,239	252,766	1,403,345	354,014	1,965,469
1981	10,643	13,680	273,334	1,493,431	351,329	1,919,577
1982	11,274	13,715	278,860	1,407,878	339,246	1,712,746
1983	12,111	14,050	287,549	1,522,737	333,583	1,766,516
1984	12,950	14,453	317,628	1,704,688	354,496	1,902,554
1985	13,528	14,531	324,064	1,735,216	348,082	1,863,820
1986	14,342	14,940	346,911	1,914,064	361,366	1,993,817
1987	15,175	15,175	326,613	2,008,693	326,613	2,008,693
1988	16,079	15,431	314,842	2,142,151	302,732	2,055,807
1989	17,513	16,052	338,661	2,311,241	310,413	2,118,461

[a] Source: Regional Economic Information System, Bureau of Economic Affairs 1991.

[b] Real dollar figures were computed using the "Implicit Price Deflator for Personal Income Expenditures," with the base year being 1987; the deflators were obtained from the Regional Economic Information Staff, Bureau of Economic Affairs.

2.2.8.3 Transportation

The City of St. Louis and St. Louis County are served by air, rail, water (river barge), and highway transport systems. In addition, there are mass transit systems, including buses and the Metro Link, the light-rail system. The key transportation systems potentially impacted by the SLDS cleanup activities are the local highways, roadways, and major railroads.

The major interstate highway routes associated with the St. Louis area are I-44, I-55, I-64, I-70, I-170, and I-270. The interstate highways are well traveled with average daily volumes equaling almost 140,000 cars on I-170 and over 100,000 cars on I-70. The roadways surrounding the downtown area are not traveled heavily. The 1991 average weekday volume northbound on North Broadway at Buchanan Street was 3,600 vehicles. The 1990 average weekday volume northbound on North Broadway at Salisbury Street was 3,900. According to the Department of for the city and the county are shown in Tables 2-8 and 2-9. Table 2-8 compares unemployment rates Streets, a traffic count in this range is considered to be very light (City of St. Louis, Department of Streets 1992).

2.2.8.4 Community and Institutional Issues

The economy of St. Louis is typical of a large metropolitan area where a mixture of commercial, industrial, and residential uses occur. St. Louis is also a transportation center. Citizen concerns about air quality, traffic congestion, crime, infrastructure, and human services have been recognized and are being evaluated (EWGCC 1991).

Community involvement in FUSRAP activities at the St. Louis site has included meetings with the St. Louis County Radioactive and Hazardous Waste Oversight Commission and the Coalition for the Environment which formed the nucleus of the St. Louis Site Remediation Task Force which formed in September 1994. The Task Force was organized to identify and evaluate remedial action alternatives for the clean up and disposal of radioactive waste materials at the St. Louis sites and at West Lake Landfill. The Task Force, after publishing the *St. Louis Site Remediation Task Force Report* in September 1996 was replaced by the Oversight Committee in December of 1996. Meetings have been held with the St. Louis Airport Authority. Workshops and meetings have been held with legislators, local mayors, and staff members of elected officials in order to keep them informed. As part of the effort to inform as many people as possible about the St. Louis site, a Speakers Bureau and an Information Center were established. Presentations have been given to such groups as the Berkeley Betterment Commission, public school groups, Kiwanis group, and the Grace Hill Association. Interviews have been held with local radio and newspaper media. These meetings have provided information and updates on site activities to these groups. Feedback has been solicited by DOE and USACE on the cleanup approach for the St. Louis site.

2.2.8.5 Public Services

Because of the industrial nature of the SLDS location, capacity and adequacy of utilities in the site area are good. They were designed for the heavy water, sewer, and power demands of industrial users. The focal point of energy management in county government is the Department of Public Works. This department coordinates the energy management activities of county government departments and buildings and provides technical assistance to municipalities, state and federal agencies, and private agencies. Ample supplies of electrical and natural gas services are available in the area. Public utilities in the area of the St. Louis site include Union Electric, Laclede Gas, Metropolitan St. Louis Sewer District, City of St. Louis Water Division, and St. Louis County Water Company.

Public health care services are provided to St. Louis County residents by county government through the four divisions of the Department of Community Health and Medical Care—County Hospital, Public Health, Emergency Medical Services, and the Medical Examiner's Office (St. Louis County, Department of Planning 1986). Another service provided by the County Government through the department is emergency medical services. Emergency medical services provides first-response ambulance service and a full advanced life support system to residents in areas not covered by municipality, fire district, or private contract ambulance service. Back-up service is also rendered on a county-wide basis.

Large and small hospitals are available in the St. Louis metropolitan area. Two particular hospitals have personnel trained in procedures to deal with cases involving radiological contamination: Christian Hospital-Northeast and Barnes Hospital.

The Emergency Readiness Assurance Plan outlines the goals and annual requirements of the FUSRAP emergency response program. The levels of radioactive and hazardous material contamination at FUSRAP sites do not pose any acute health risk to either onsite workers or the general public in credible accident scenarios. The predominant risks are to onsite personnel in association with construction activities and onsite building fires. Plausible off-site risks include exposures to hazardous materials and/or radioactivity through spills into surface waters, onsite building fires, or direct contact following a transportation accident. FUSRAP emergency planning emphasizes spill control and cleanup techniques. The plan specifies that during emergency incidents originating on or impacting FUSRAP sites, off-site emergency responders would be coordinated by USACE or its contractor representative in charge of emergency management. The site-specific safety and health plan for the St. Louis site delineates emergency management authority for the site. USACE would coordinate with local emergency responders at least annually to provide an opportunity for site tours and to assure off-site preparedness.

2.2.9 Historical, Archaeological, and Cultural Resources

Two sites listed in the March 1992 edition of the National Register of Historic Places for the State of Missouri exist within a 1.6-km (1-mi) radius of SLDS. The first site is the Bissell Street Water Tower, located approximately 1.3 km (0.8 mi) northeast of SLDS, at the intersection of Bissell Street and Blair Avenue. The second is the Murphy-Blair Historic District, bounded by I-70 on the east, North Florissant Avenue on the west, and Branch and Chambers Streets on the north and south, respectively. The northwestern tip of the Historic District is located 0.8 km (0.5 mi) from SLDS, and the entire District covers approximately 1.3 km^2 (0.5 mi^2) and 75 square blocks (DOI 1992).

SLDS does not contain any historic buildings listed with SHPO nor under the National Register of Historic Places. Buildings 25 and K were built in approximately 1935 and 1903, respectively. The 50-series buildings in Plant 2 were built in 1941. All of these buildings were constructed by Mallinckrodt for industrial purposes and have been operated as such since their construction. A cultural resources survey of the SLDS buildings on the Mallinckrodt Inc. property that could be potentially impacted has been conducted in accordance with Section 106 of the National Historic Preservation Act of 1966 (Historic American Buildings Survey 1997). The National Park Service has acknowledged that this documentation satisfies the requirements of the National Historic Preservation Act.

Available data indicate no archaeological sites in the area. However, no archaeological survey of the property has been conducted. The site is covered by a fill layer averaging 4 m (13 ft) which overlies alluvial deposits extending between 6 m (19 ft) and 24 m (80 ft). The degree of disturbance beneath the fill layer is not presently known. If the alluvial deposits are relatively undisturbed, archaeological deposits may exist in this area. The property is approximately 0.4 km (0.25 mi) from the former location of a mound group, the St. Louis Mounds. Archaeological deposits from that occupation may occur in alluvial soil under the fill (personal communication, Harl 1992). However, considering the intensive industrial use of the site, it is unlikely any significant archeological sites exist at SLDS.

Consultations have been conducted with Native American groups and the Missouri SHPO. Discussions indicate that the disturbance of Native American burials is the primary concern of the Native American groups in Missouri. If intact sites exist underneath fill, there is a potential for uncovering human remains.

2.3 NATURE AND EXTENT OF CONTAMINATION

An RI was conducted in accordance with CERCLA to determine the nature and extent of contamination, and to characterize the geological and hydrogeological features of the St. Louis site. Analytical results for radiological and chemical characterization surveys are summarized in the RI report (BNI 1994a), RI Appendices, and the RI Addendum (SAIC 1995). Analyses performed during characterization included Th-230, Th-232, Ra-226, U-238, volatile organic compounds (VOCs), base neutral and acid extractable compounds (BNAEs), metals, Resource Conservation and Recovery Act (RCRA)-hazardous waste characteristics, pH, specific conductance, total organic halogens, and total organic compounds (TOC). The results of this investigation for the SLDS are summarized in this section.

A review of the past uranium processing activities at SLDS indicates chemical contamination consists primarily of elemental metal compounds. Non-radiological chemicals and metals were both contained in uranium ores and used in uranium processing operations. Based on ore assays and waste analyses, metals that may have been introduced with ores include arsenic, barium, boron, cadmium, chromium, cobalt, copper, gold, iron, lead, magnesium, manganese, molybdenum, nickel, palladium, platinum, selenium, silver, vanadium, and zinc. Chemicals associated with MED/AEC materials or processes include trichloroethylene (TCE), diethyl ether, inorganic compounds such as hydrofluoric, nitric, and sulfuric acids (Harrington and Ruehle, 1959), nitrates, calcium hydroxide, caustic soda, sodium bicarbonate and carbonate, anhydrous ammonia, graphite, and petroleum products. Of these, the chemicals and metals with potential impact on human health and the environment include arsenic, barium, cadmium, chromium, copper, lead, molybdenum, nickel, selenium, vanadium, zinc, polycyclic aromatic hydrocarbons (PAHs), and trichloroethylene. Although thallium and PAHs were previously listed as potential concerns, these substances are not attributable to MED/AEC operations and thus have been deleted as PCOCs. With regard to PAHs, this approach will be verified through a background study that is being conducted.

The potential for non-MED/AEC industrial process-related organic and inorganic releases from the Mallinckrodt Inc. facility and surrounding businesses is substantial given the nature and duration of industrial activities (i.e., chemical production and packaging since the mid-1800s) in the downtown area. Radionuclides were also introduced into the environment as a result of columbium-tantalum processing at Mallinckrodt Inc. performed under NRC license. The columbium-tantalum processing was not performed for the U.S. Government.

Chemicals and radionuclides not associated with MED/AEC-related uranium processing activities are present. Substantial development has taken place at the site since the early 1940s. This development may have affected the distribution of chemicals present in soil across the site. For these reasons, the chemical characterization did not focus on a limited number of compounds at isolated locations. Rather, analyses for a wide range of chemical compounds in broad chemical groups were conducted on samples collected from numerous locations known to be radiologically contaminated.

Criteria have been selected to designate soil volumes for the SLDS program. The criteria used to include volumes contaminated through MED/AEC uranium processing activities, which are within the scope of the project, follow.

- Areas having levels of radioactivity above background where the extent of contamination can be traced to MED/AEC uranium processing activities are included.

- Elevated levels of organic and inorganic chemicals that cannot reasonably be traced to a single business or industry given the diversity of industries in the immediate area will be disposed if they are commingled with MED/AEC radionuclide concentrations greater than the selected removal criteria and/or require excavation for the SLDS remedial operations.

- Areas containing elevated levels of organic and non-radioactive inorganic chemicals traceable to known MED/AEC uranium processing activities are included (however no such areas have been identified based on history and sampling data).

Soil volumes contaminated through other activities, which are outside the scope of this project, are designated as follows:

- Elevated radiation areas where the extent of contamination can be traced to non-MED/AEC uranium processing activities (eg, Mallinckrodt Inc.'s columbium-tantalum operation) are excluded. Similarly, radiologically contaminated areas of SLDS characterized as being free of residuals associated with uranium processing activities are beyond the scope of the FFA, and are not addressed in this FS.

- Areas exhibiting background levels of radioactivity and containing no MED/AEC chemical constituents are considered free of any residues associated with uranium processing activities, and are excluded.

- Elevated levels of organic and non-radioactive inorganic chemicals in the downtown area that cannot reasonably be traced to a single business or industry given the diversity of industries in the immediate area will be excluded unless they are mingled with MED/AEC radionuclide concentrations above the selected removal criteria or are otherwise directly attributable to MED/AEC operations.

Determination of the SLDS potential contaminants of concern (PCOCs) is based on the EPA guidelines for data evaluation (EPA 1989a) and for data usability in risk assessment (EPA 1990) as described in Section 2.5 of the BRA. The MED/AEC PCOCs which exceed the criteria of cancer risk in excess of EPA's target carcinogenic risk (range of 10^{-6} to 10^{-4}) and/or noncarcinogenic hazard rating of 1.0 would require mitigation under the remedial action.

Soil samples were analyzed and passed analyses for leaching, corrosivity, ignitability, and reactivity. While some previous analyses performed using the EP-TOX analytical method showed positive results for lead, additional sampling using the toxicity characteristic leaching procedure (TCLP) analytical method did not confirm these results. The TCLP sampling encompassed the entire site, including all the areas which had previously failed EP-TOX for lead. A summary of the TCLP results are presented in Table 2-13 for all TCLP constituents detected.

Table 2-13. Chemicals Detected in TCLP Tests

Analyte	Results > Detection Limit	Minimum Detected (mg/L)	Maximum Detected (mg/L)	Average Result* (mg/L)	TCLP Limit (mg/L)
Barium	43/51	0.268	1.84	0.847	100
Cadmium	21/51	0.0051	0.13	0.017	1
Chromium	3/51	0.0172	0.0184	0.0116	5
Lead	19/51	0.0563	9.01	0.469	5
Silver	1/51	0.0889	0.0889	0.0125	5
Trichloroethylene	1/38	0.110	0.110	0.0271	0.5

*Averages were computed by setting results below the detection limit to ½ the detection limit

Soil samples collected at SLDS indicate contamination is widespread across SLDS as illustrated in Figures 2-7, 2-8, and 2-9. The brown areas in these figures indicate remedial actions taken at City Block 1210 and on the route for the bicycle trail along the levee on City Property. These figures were prepared by projecting the highest detected value from each boring to the surface (ie, for each boring, the maximum concentration at any depth is used in construction of the figures). As these figures show, uranium is essentially limited to Mallinckrodt Inc. Thorium and radium are widespread across SLDS, although the areas of highest concentrations are restricted to Mallinckrodt Inc.

The principal radioactive constituents found at SLDS are Ra-226, Th-230, Th-232, U-234, U-235, U-238, Pa-231, Ac-227, and their respective radioactive decay products. Maximum detected concentrations are: 95,000 pCi/g for U-238, 2800 pCi/g for Ra-226; 98,000 pCi/g for Th-230; and 640 pCi/g for Th-232 (DOE 1994). Depths of contamination range from the surface to 7 m (23 ft) on the Mallinckrodt Inc. property and to 4 m (13 ft) under the levee on adjacent property owned by the City of St. Louis. The estimated volume of radiologically contaminated soil at SLDS is 80,000 m^3 (105,000 yd^3) at Mallinckrodt and an additional 12,000 m^3 (15,000 yd^3) on the vicinity properties (Table 2-14) using the most stringent criteria.

Organic compounds commonly found in industrial areas were detected in very low concentrations (ranging from 1 to 430 μg/kg) across the property; approximately two-thirds of these are PAHs. Of the VOCs found, only TCE is suspected to have been used in the uranium processing. BNAEs, identified as PAHs, were found in higher concentrations (ranging from 310 to 300,000 ppb) than were VOCs, but they are typically not very mobile in soil. No pattern of BNAE distribution in soil was discernible across the site; these compounds appear to be evenly distributed. Borings exhibiting the highest concentrations of semivolatiles were widely spaced across the site in Plants 1,

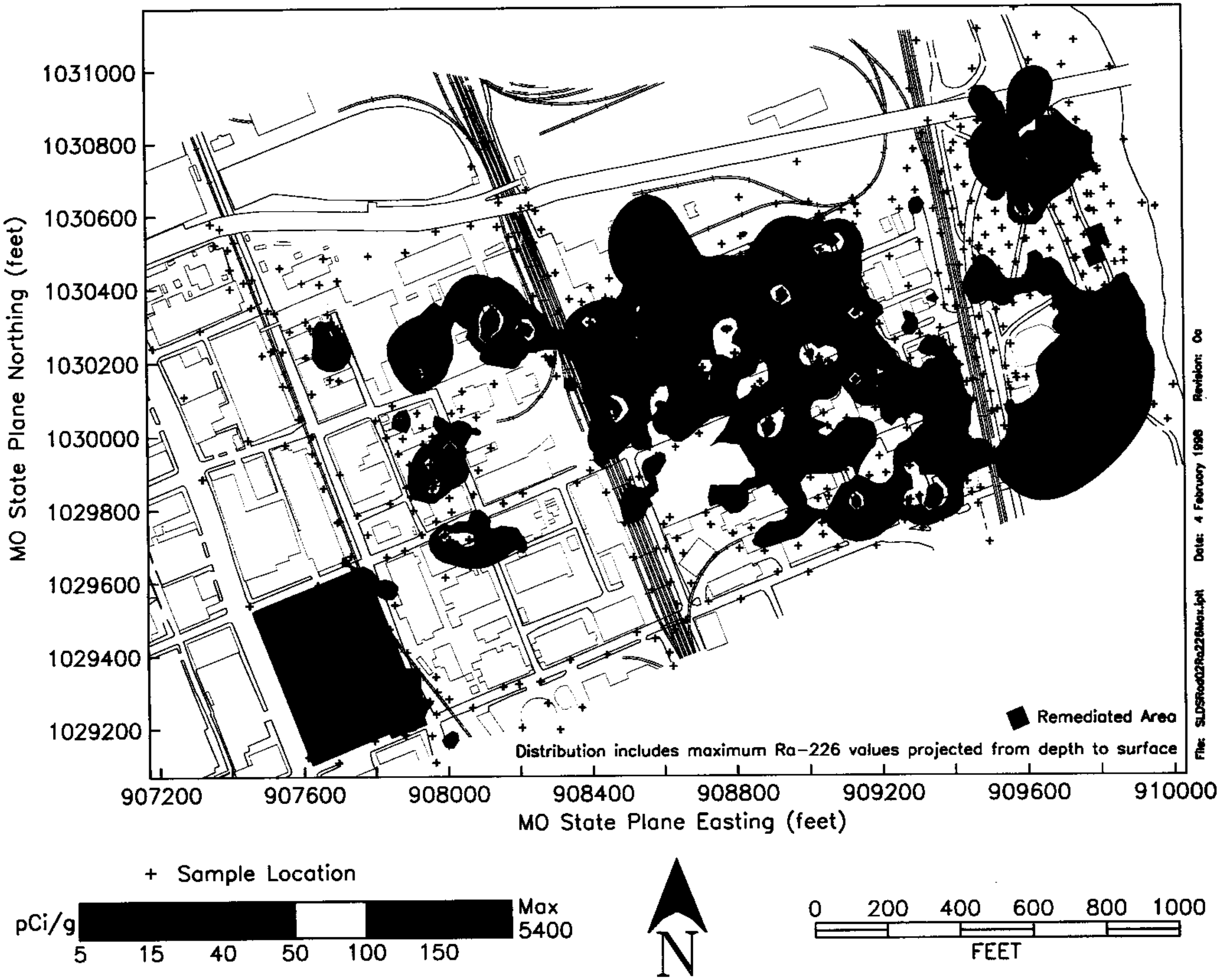


Figure 2-7. Extent of Ra-226 Contamination at SLDS

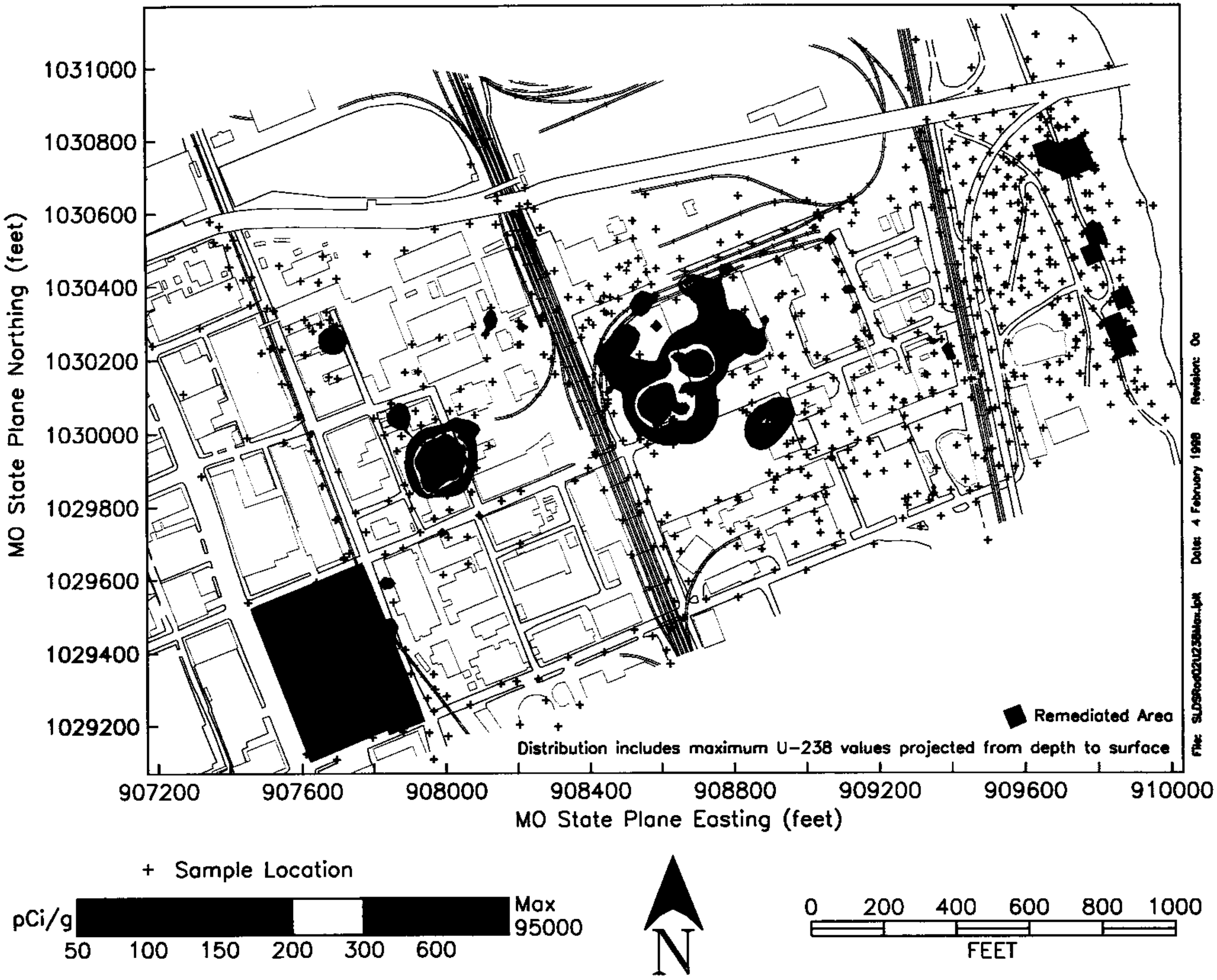


Figure 2-8. Extent of U-238 Contamination at SLDS

Figure 2-9. Extent of Th-230 Contamination at SLDS

Table 2-14. Volumes of Contaminated Soil (yd^3) at SLDS

Location	0 to 2 ft	2 to 4 ft	4 to 6 ft	Below 6 ft	Total
Mallinckrodt Inc. 7E					
Accessible	372	31	9	4	416
Inaccessible	0	0	0	0	0
Mallinckrodt Inc. East					
Accessible	21,579	8,370	5,558	17,442	52,949
Inaccessible	3,603	3,664	3,275	12,416	22,958
Mallinckrodt Inc. Central					
Accessible	5,804	1,868	1,913	13,896	23,481
Inaccessible	3,146	350	169	751	4,416
Mallinckrodt Inc. West					
Accessible	407	1	0	0	408
Inaccessible	352	0	0	0	352
CB&Q Railway					
Accessible	0	0	0	0	0
Inaccessible	1,217	20	0	0	1,237
City Property					
Accessible	3,984	938	589	941	6,452
Inaccessible	0	0	0	0	0
McKinley Iron					
Accessible	1,391	1,262	591	311	3,555
Inaccessible	249	288	19	0	556
N&W Railway					
Accessible	0	0	0	0	0
Inaccessible	988	46	0	0	1,034
PVO Foods					
Accessible	3	0	0	0	3
Inaccessible	0	0	0	0	0
St. Louis Terminal RR					
Accessible	0	0	0	0	0
Inaccessible	1,260	64	2	10	1,336
Thomas & Proetz Lumber					
Accessible	530	0	40	7	577
Inaccessible	398	0	11	1	410
Total	45,283	16,902	12,176	45,779	120,140

7W, and 10 (BNI 1990). The PAHs that occurred with the greatest frequency at the site are those associated with coal combustion residues (Swann 1983). Additionally, PAHs are widespread in any urban area which has been subject to continuous industrial development since the mid 1800s and thus cannot be attributed solely to a single process.

Metals were found in radiologically contaminated soil in excess of background concentrations, however; high detection limits on the metals analyses makes the data difficult to interpret. The source of elevated metal concentrations is not known. Like PAHs, a probable source of elevated metal concentrations in soils is the coal cinders and ash used as fill throughout the area as well as from uranium processing activities.

Sediment sampling was conducted in the Mississippi River along the city property in 1987–1988 when the river level was low. Results indicated the primary PCOCs in the river sediment were Th-230, with average concentrations ranging from 1 to 160 pCi/g, and Ra-226, with concentrations ranging from 6 to 1,100 pCi/g. Additional sampling conducted in 1992 to confirm earlier results yielded contaminant levels of <1 pCi/g for both Th-230 and Ra-226 essentially at background levels (SAIC 1995). Evidently, periods of high water between 1988 and 1992 redistributed the PCOCs in the sediment.

Some groundwater contamination was detected in monitoring wells on the Mallinckrodt Inc. property during the remedial investigation. Uranium significantly above background was detected in four shallow onsite wells, including B1602S (162 pCi/L total U), B1613S (147.9 pCi/L total U), B1611S (30.3 pCi/L total U) and B1607S (5.3 pCi/L total U, 8.5 pCi/L Ra-226, 5.5 pCi/L Th-232, and 5.8 pCi/L Th-230). These results are generally consistent with the preliminary results of sampling conducted during late 1997 and early 1998. The background activity levels for total uranium range between 0.2 and 4 pCi/L. Wells screened in the lower hydrostratigraphic unit and in the bedrock beneath this unit have consistently shown radionuclide concentrations well below tap water quality standards. Chemical analyses of groundwater samples detected twelve elevated metals. Results for fluoride indicated that groundwater exceeded the secondary maximum contaminant level (MCL) for tap water (2,000 μg/L) with a maximum level of 6,200 μg/L. Seven VOCs, including acetone, benzene, trichloroethylene, 1,2-dichloroethene, vinyl chloride, 1,2-dichloropropane, and chlorobenzene, have been detected at very low concentrations ranging between 5 and 150 μg/L in groundwater samples throughout the groundwater beneath SLDS. Tetrachloroethylene was detected in one well (W03S) below quantifiable limits.

Two semivolatile organic compounds (SVOCs) (hexachlorobutadiene and 1,2-dichlorobenzene) were detected and eight SVOCs [1,4-dichlorobenzene, 2,2-oxybis(1-chloropropane), n-nitrosodiphenylamine, phenol, carbozole, bis(2-ethylhexyl)phthalate, di-n-butylphthalate, and diethylphthalate] were detected below quantifiable limits. The pesticide 4,4'-DDT was detected at approximately 1 μg/L in well W07D and the PCB Aroclor-1254 was detected at approximately 1.5 μg/L in well W04S. The organic compounds that were detected and exceeded tap water standards included benzene, trichloroethylene, 1,2-dichloroethene, vinyl chloride, and tetrachloroethylene.

Metals detected in groundwater included aluminum, arsenic, boron, barium, calcium, cadmium, chromium, copper, iron, magnesium, manganese, nickel, potassium, selenium, sodium, and zinc. Iron, manganese, and aluminum far exceed tap water standards throughout the groundwater beneath SLDS and this condition is characteristic of the Mississippi and Missouri Rivers alluvial aquifers (Miller, 1974). In addition, cadmium and selenium slightly exceeded tap water standards in one well each (W01S and W08D, respectively) during the RI, and preliminary results from the 1997/98 sampling activity indicates that cadmium again slightly exceeded the tap water standard in well W04S.

Twenty buildings at SLDS were surveyed; 17 contained surface contamination greater than NRC concentration based release criteria. Building surveys show that U-238 was the primary radioactive contaminant in the majority of these onsite buildings. However, Ra-226 was the primary contaminant above criteria in two buildings surveyed. Three of the buildings were found to approach the 0.02 Working Level (WL) 40 CFR 192 guideline for allowable exposure to radon gas (BNI 1994b). Since the remedial investigation, all but three of the buildings have been demolished. Building K is scheduled for demolition and will be removed before remedial action at SLDS is implemented. Building 101 does not contain any surface contamination, but was constructed on top of contaminated soil. Building 25 is an active operational facility in which the surface criteria were exceeded in some areas. Since the RI, extensive remodeling and painting has resulted in a reduction in the potential for employee exposures. Through historical information and as a result of building remodeling activities there is evidence that asbestos does exist in the buildings at SLDS.

Sediment samples taken from some of the manholes, catch basins, and sewers at SLDS exhibited radioactive contamination exceeding generic guidelines (SAIC 1995). The depth of soil contamination at SLDS generally exceeds 1 m (3 ft) and most sections of old sewer lines are in the accessible contaminated areas. However, some section of these older sewer lines are beneath buildings and are therefore inaccessible. Concentrations within Plants 6 and 7 ranged up to 2,662 pCi/g of Th-230 and up to 270 pCi/g of U-238. Concentrations within Plant 1 ranged up to 21 pCi/g of Th-230 and up to 30 pCi/g of U-238. Based on the observation that contamination levels decrease with increasing distance from the site, the possibility that an accumulation of contaminated sediment of appreciable quantity exists off-site seems quite remote. With increasing development in the area and collection of all effluent for treatment, the water load on the system has increased. This would increase the likelihood that most of the loose deposits in the system have already been scoured away.

Potential Contaminants of Concern

The primary radioactive PCOCs in soils and sediments are Ra-226, Th-232, Th-230, U-238, U-235, and their decay products (including Ac-227 and Pa-231 from the actinium decay series). Radionuclides in groundwater include Ra-226, Th-230, uranium, and their decay products. Several metals, inorganic anions, and organic compounds were detected in the soils, sediments, and groundwater at SLDS. The PCOCs identified in the BRA (ANL 1993) for soils and sediments include antimony, arsenic, beryllium, cadmium, cobalt, lead, nickel, thallium, uranium, and PAHs. The BRA identified PCOCs in groundwater as well. The decision as to whether a constituent should be included on the PCOC list in the BRA did not include a consideration of the source of the constituents. Therefore, even constituents present at background levels, but exceeding risk screening levels, may have been carried forward onto the PCOC list in the BRA. EPA guidelines (EPA, 1990) were followed in determining the list of potential contaminants of concern. All detected compounds were screened against background concentrations and chemicals classified as essential nutrients. Analyses to date for corrosivity, ignitability, TCLP, and reactivity indicate that the soils are not RCRA characteristic wastes. No RCRA listed compounds were used in the MED/AEC uranium processes. Lack of leachability when taken together with comparison of partitioning/distribution coefficients supports the conclusion that radioactive materials and non-radiological PCOCs are co-located without significant migration of non-radiological PCOCs outside of volumes which must be remediated with respect to radioactive PCOCs. Compounds are herein included as PCOCs only if

MED/AEC related. Several inorganic constituents were included in the BRA but 1) were never detected at the site, 2) were not MED/AEC related, or 3) do not pose significant risk based on the anticipated land use. Therefore, they are specifically excluded from the PCOCs carried forward.

In general, the highest levels of contamination are on the Mallinckrodt Inc. property, with the principal radioactive contaminants being Ra-226, Th-230, and U-238. Access to Mallinckrodt Inc. is restricted. The vicinity properties exhibit lower concentrations of radionuclides.

There are contaminants in the soil and groundwater from onsite sources unrelated to MED activities. As discussed previously, many of the organic and non-radioactive inorganic chemicals detected during the RI cannot be attributed to one source, industry, or event due to the history and diverse nature of industries located at the downtown site. The same holds true for radionuclides. Radioactive materials at SLDS can be attributed to natural accumulation in coal combustion residue used as fill, MED/AEC uranium processing activities, and other radionuclide materials processing. The MED/AEC operations were performed in different areas of the plant site from other radiological processing activities and thus can be roughly delineated. Remediation of MED/AEC radiologically contaminated portions of the SLDS is clearly within the scope of the FFA. This Agreement involved the following types of materials.

- All wastes, including but not limited to radiologically contaminated wastes and metals associated with the ores, resulting from or associated with MED/AEC uranium manufacturing or processing activities conducted at SLDS; and,

- other chemical or non-radiological wastes that have been mixed or commingled with radiologically contaminated wastes resulting from or associated with MED/AEC uranium manufacturing or processing activities conducted at SLDS (DOE 1990).

The remediation of non-MED/AEC wastes will be undertaken only when commingled with MED/AEC wastes.

The BRA used the available analytical data to characterize the risks associated with the St. Louis site. Data were obtained from areas at SLDS on organic and non-radioactive inorganic chemicals and radionuclides irrespective of whether or not they are associated with MED/AEC uranium activities. Limited groundwater data for SLDS was evaluated without regard to background levels in groundwater and may have resulted in the BRA analysis overestimating the number of PCOCs. Consequently, this could have resulted in elevated risk estimates. The presence of multiple industry sources for chemical and radionuclide contamination complicates SLDS. Consistent with the BRA analysis, protection of human health and the environment will be achieved by mitigating MED/AEC-commingled wastes. Areas contaminated only with non-radioactive PCOCs attributable to MED/AEC uranium activities have not been found and are not anticipated based on technical analyses. As such, remediation of non-radiological PCOCs which are not co-located with radiological PCOCs can be accomplished only if the constituent of interest can clearly be shown to have originated from MED/AEC operations. Consistent with the FFA, any non-MED/AEC contaminated areas are not considered within the scope of the SLDS FS.

Potential contaminants of concern consisting of chemicals and metals associated with the MED/AEC process which have been detected at concentrations exceeding 1 × 10^{-6} industrial risk criteria are limited to arsenic, cadmium, copper, and nickel. Concentrations of one or more of these PCOCs may be the result of site background concentrations rather than from MED/AEC activities. As such, a background study is being conducted to verify concentrations of chemicals and metals present at SLDS. Efforts to determine background concentrations of chemicals and metals may result in elimination of one or more constituents from the list of non-radiological contaminants of concern. This study may result in elimination of one or more constituents from the list of nonradiological PCOCs based on verification that the material does not result from MED/AEC activities in quantities exceeding CERCLA risk criteria. The list of contaminants of concern will be finalized and incorporated into the Record of Decision.

2.4 CONTAMINANT FATE AND TRANSPORT

The fate and transport of site contaminants was assessed to identify the environmental media that could be impacted by releases from onsite source areas. Possible release mechanisms at SLDS include the following:

- potential external gamma irradiation from areas contaminated with radionuclides (ie, areas of contaminated soil, building interiors, drains, and manholes);
- radon gas generation from radium-contaminated soil, groundwater, and building surfaces;
- wind dispersal of contamination, including fugitive dust generated from contaminated site soil;
- surface deposition of airborne particulates (eg, fugitive dust generation or release of building contaminants);
- surface runoff over contaminated soil following precipitation, with transport to other onsite soil and drainage areas;
- leaching from contaminated surface and subsurface soil areas to groundwater;
- transport of contaminated fine-grained soil particles from surface and subsurface soil to groundwater;
- transport of soil from depth to the surface by excavation associated with maintenance and construction;

- transport of contaminated soil particles from groundwater to surface water and sediment; and
- contaminant uptake by biota (ie, animals and plants) from contaminated soil.

Some potential release mechanisms and receiving media do not play a primary role in contaminant fate and transport leading to current human exposure at SLDS due to site-specific environmental factors. These mechanisms include wind dispersal of building contamination with eventual surface redeposition of such contaminants and uptake by biota of contaminants from soil. Building contamination at SLDS has been found to be primarily fixed, although small amounts of removable contamination have been detected. Uptake by biota is not an important release mechanism because of the industrial nature of the site. Finally, although contaminated shallow groundwater has been identified on site, the groundwater in the area of the site is not used for drinking or other household purposes (ANL 1992). The fate and transport of contaminants in groundwater is naturally controlled by the low permeability of the geologic materials of the upper hydrostratigraphic unit. Low groundwater flow rates coupled with significant retardation factors characteristic of the radionuclides of primary concern greatly retard off-site migration.

The major surface water body potentially impacted by site contaminants via runoff from SLDS is the Mississippi River. Contaminated soil particles may be transported via groundwater or storm water into the Mississippi River. Any contamination that might be transported into the Mississippi River water column would be reduced to below detectable levels by dilution. Three Mississippi River sediment samples were collected from locations adjacent to SLDS to determine sediment radionuclide levels in the Mississippi River. Because the river near the SLDS is deep and relatively fast flowing, direct human contact with the sediment, such as through wading or swimming, was considered unlikely and, therefore, was not assessed in the BRA. However, an evaluation of the potential exposure from consumption of fish caught in the Mississippi River was included in the BRA; this pathway was evaluated for the recreational user at the city property adjacent to SLDS (ANL 1992).

The BRA used a residential future land-use scenario for the site to model the effect on a maximum exposed individual. Conservative assumptions were made including the potential use of groundwater for drinking and other household uses such as showering. The possibility of a farm with animals was not considered for the future scenarios because all of the properties are in areas that are likely to remain urban. A scenario in which a home garden is planted to provide edible produce was assumed because this was considered plausible under the residential scenario. The residential land use scenario was included in the BRA for information purposes and because it is usually required in a BRA. Discussion is included here of potential risk through residential exposures to soil and groundwater to clarify the implications of unexpected exposure conditions.

In summary, the environmental release mechanisms and transport pathways that are considered most important for potential human exposures to site contaminants under current conditions are:

- external gamma radiation from radiologically contaminated materials (including soil and structural surfaces);
- radon gas generation from radium-contaminated soil and structural surfaces;
- wind dispersal of fugitive dust generated from contaminated site soil; and
- transport of soil from depth to surface during excavation activities.

Other release mechanisms and transport pathways that might become factors in future scenarios include leaching of soil contaminants to groundwater, contaminated soil particle transport in groundwater, and bio-uptake of soil contaminants by plants.

2.5 SUMMARY OF BASELINE RISK ASSESSMENT

A BRA was conducted (ANL 1993) to evaluate potential risks to human health and the environment from contaminants at the St. Louis site. The risk assessment used all of the currently available radiological and chemical contaminant characterization data, estimates of exposure pathways, and both current and hypothetical future risk scenarios for the properties. Thus, the BRA did not differentiate between contaminants originating from MED/AEC activities and those resulting from non-MED/AEC activities.

Reasonable maximum exposure in both current and hypothetical future use scenarios, and carcinogenic risks and non-carcinogenic health effects were estimated and compared to EPA's target carcinogenic risk and hazard index, respectively. The EPA's acceptable exposure levels for carcinogenic risk are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-6} and 10^{-4}, using information on the relationship between dose and response. For purposes of comparison, about one in three Americans will develop cancer (ACS 1992). That is, the cancer risk posed to a U.S. citizen from the multitude of risks and factors averaged across the U.S. would cause a one in three cancer rate. The EPA hazard index is a measure of the potential for adverse non-carcinogenic health effects due to exposure to site related chemicals. A hazard index of one or greater indicates that there may be a concern for non-carcinogenic effects associated with exposure to site related chemicals. It should be noted that chemicals present at SLDS cannot be linked exclusively with MED/AEC activities. The scope of FUSRAP activities is limited to remediation of MED/AEC contamination. Chemical contaminants not associated with MED/AEC activities will be addressed only when they are commingled with the radiological contamination.

Background health effects (ie, those associated with naturally occurring levels of the radionuclides and metals found at the site) influence the development of health-based cleanup criteria. Radiological risks estimated for a resident from exposures to site contaminants should be considered in the context of risks from background radiation. The risks associated with natural levels of radioactivity exceed the 10^{-4} upper limit of EPA's target range for an individual's excess lifetime cancer risk. In fact, the lifetime risk associated with background levels of radon-222 and its short-lived decay products alone is estimated by EPA to be about 1×10^{-2} (EPA 1989b).

Because of the inherent uncertainties in the risk assessment process, the results of the human health assessment presented in the BRA should not be taken to represent absolute risk. Rather, they should be considered to represent the most important sources of potential risk at the site. Inherent in each step of the risk assessment process are uncertainties attributable to the numerous assumptions incorporated in the risk estimations. Most of the assumptions used in the BRA tend to overestimate the potential risks. One factor for affecting the potential overestimation of risk may be the use of maximum measured values as exposure point concentrations for contaminants in groundwater. At the time the BRA analysis was performed, the available data for groundwater were not as extensive as data available for site soil. For similar reasons, maximum gamma exposure rates, as well as maximum radon and fixed structural contamination concentrations were used as exposure point concentrations in the estimation of current indoor risk to the SLDS employee and construction worker. Furthermore, standard worker protection measures required by law are not factored into the worker exposure scenarios. Therefore, actual risks are likely to be lower than those presented in the BRA.

2.5.1 Results of the Assessment

The results of the human health risk assessment, which did not differentiate between MED/AEC and non-MED/AEC sources, indicate that the highest potential health impacts associated with the St. Louis site result from postulated future exposures at the Hazelwood Interim Storage Area (not addressed in this FS). The highest risks for all workers are from exposure to radiological contaminants. Under current site conditions and uses and on the basis of the assumptions used in the BRA, the potential health impacts at SLDS are highest for the construction worker. The estimated risks to the construction worker from exposure to radionuclides at SLDS exceeds the upper end of the EPA's target carcinogenic risk range (ANL 1993).

Data used in the BRA for assessing the baseline groundwater pathway future resident scenario were mainly from the environmental monitoring efforts at SLAPS and HISS. During the BRA analysis, only limited groundwater data were available from monitoring wells located at SLDS. Because background levels of groundwater in these areas were unavailable, most radiological and chemical analytes that were detected were considered as PCOCs. The highest concentrations found in groundwater for both radiological and chemical were used in the baseline risk calculations. A few chemical analytes (metals) were screened out because they were considered to be essential to the human diet. The inclusion of most analytes in the assessment may have resulted in overestimating the number of PCOCs attributable to MED/AEC activities at these properties and consequently, may have overestimated the risk estimates for the receptors from MED/AEC contaminants (ANL 1993). In addition, results from a conservative trespasser scenario assessed for this site indicated that potential risks would be within the target risk range for chemical exposure and just slightly above the target risk range for radiological exposure (ANL 1993). Under hypothetical future site conditions and uses, the potential noncarcinogenic and carcinogenic health impacts to future residents at all site areas assessed exceed the upper end of the target values.

An ecological assessment was conducted to evaluate potential effects from contamination of the St. Louis site. Due to the urban environment, the downtown area has limited habitat and biotic diversity. The ecological assessment compared contaminant concentrations detected in various media (soil, sediment, and water) at the site with literature on the toxicities of the contaminants to biota. This study indicated that only arsenic, thallium, and PAHs are at concentrations that could potentially impact biota. Ecological effects, however, are not expected to be a significant concern because no unique habitats or biota exist at the site, the biota are not necessary for continued propagation of key species, and there are no species at SLDS that are highly valued economically, recreationally, or aesthetically (ANL 1992).

2.5.2 Potential Receptors and Routes of Exposure

The receptors identified for current site use include an employee, a construction worker, and a maintenance worker. Exposure pathways assessed for current scenarios were external gamma irradiation, incidental soil ingestion, inhalation of particulates, and inhalation of Rn-222 and its decay products. For the current employees at SLDS, only potential exposures from external gamma irradiation and radon inhalation were assessed because SLDS is almost completely covered with buildings and pavement. However, ingestion and inhalation of particulates were assessed for a SLDS construction worker because of potential exposure during excavation or renovation activities. No current scenarios included contaminated groundwater as a source because the water is considered to be of naturally low quality and it is not known to be used for any domestic purpose in the vicinity of SLDS (ANL 1993).

The hypothetical future risk scenarios included a future resident. In addition to the pathways assessed for current receptors, potential risk from the ingestion and inhalation of contaminants in groundwater (although unlikely) was also assessed for future residents. A future residential scenario at SLDS is considered unlikely because the site has been used for industrial purposes for over 100 years. Carcinogenic risk from soil ingestion was not quantified for the SLDS employee and SLDS maintenance worker because the soil ingestion pathway is intercepted by the presence of parking lots and buildings. Carcinogenic risk from chemical exposure was not assessed for the residential child commuter and residential current resident because no data were available specific to the site area.

2.5.3 Risk Estimates for Current Site Use

The radiological carcinogenic risks (including the radon pathway) estimated for current site use by the employee, maintenance worker, and city property recreational user were mostly within the EPA's risk criteria of the general range of 10^{-6} to 10^{-4}. Risk for employees inside Building K1E was the highest at 4×10^{-3}, however, this building is not currently used and is scheduled for demolition. Building K will be removed before remedial action begins. However, the radiological risk estimates for the construction worker exceeded this range under the assumptions used in the BRA. Where evaluated, the carcinogenic risk from radon and its decay products was a major portion of the overall risk from radionuclides. The total chemical carcinogenic risk for the combined pathways for each current receptor was in the 10^{-6} to 10^{-4} range.

Potential noncarcinogenic risks evaluated under all current risk scenarios were determined to be acceptable (ie, Hazard Index <1.0).

Since the BRA, several actions have been completed that reduce the risk in certain areas. Contaminated soil has been removed from the levee and Plant 10 and most of the contaminated buildings have been demolished. These actions are presented in more detail in Section 2.7.

2.5.4 Risk Estimates for Hypothetical Future Site Use

Future risk scenarios were evaluated for onsite residents. The residential land use scenario was included in the BRA for information purposes. Residential future use is considered unlikely but was included to explore the implications of unexpected severe exposure conditions. The estimated carcinogenic risk levels exceeded the 10^{-6} to 10^{-4} range. Inhalation of radon and its decay products is the largest contributor of all radiological pathways assessed for the future resident, causing approximately half of the risk from radionuclide exposure. External gamma irradiation is the largest contributor of the nonradon sources.

The future resident at the SLDS area would incur the highest chemical carcinogenic risk, primarily from the ingestion of PAHs present in soil and arsenic present in groundwater.

The calculated Hazard Index for future residents exceeded the target value of 1.0. The future residents at SLDS are estimated to incur noncarcinogenic chemical risks with a Hazard Index of 85. The high value of the Hazard Index at SLDS is primarily due to the ingestion of groundwater containing thallium and arsenic. Following remediation of the site to address MED/AEC contaminants, residual risks will remain from non-MED/AEC compounds.

2.6 PRELIMINARY REMEDIATION GOALS

Preliminary Remediation Goals (PRGs) are designed to provide long-term targets for the selection and analysis of remedial alternatives. A part of the risk assessment process, the determination of PCOCs serves as the starting point for the determination of PRGs. In this section, human health preliminary remediation goals (HHPRGs) are derived for the PCOCs that are protective cleanup levels based on risk to human receptors. PRGs are determined for protection of human health in the following sections. A range of PRGs are developed and presented that represent differing levels of protection. From these, final cleanup levels that are protective of human health, as well as compliant with ARARs will be selected for SLDS. If required, remedial activity at the site will be conducted to meet the final cleanup levels.

2.6.1 Human Health PRGs

HHPRGs were calculated for PCOCs identified in the human health risk assessment (ie, chemicals that exceed ARARs or contribute to a pathway that exceeds a hazard index of 1.0 or a cancer risk of 1×10^{-4}). The HHPRGs presented for SLDS are not unique to a given area. Rather, they are unique to the appropriate land use (for SLDS this is industrial) and environmental medium.

For this reason, the HHPRG for a given chemical at SLDS is applicable wherever that chemical is found within SLDS. The HHPRGs take into consideration simultaneous exposure via multiple pathways that were evaluated in the risk assessment. For soil the HHPRGs take into account risks from soil ingestion, dermal contact with soil, and inhalation of suspended particulates. For groundwater exposures, the HHPRGs include dermal contact and inhalation (eg, with process water). Given the highly industrial nature of the area and the naturally poor quality of the groundwater in the vicinity of SLDS, groundwater ingestion is not considered to be plausible .

USEPA has published guidance (EPA 1991) on the determination of preliminary remediation goals. HHPRGs are calculated in a manner that is similar to calculating risk. This is accomplished by setting the noncancer HI or cancer risk to the appropriate target, and solving the equation for the concentration term (ie, a back calculation).

Adopting guidance published by EPA Region IV, several options are considered by providing a range of HHPRGs for SLDS. HHPRGs are calculated using noncancer target HIs of 0.1, 1, and 3 and target cancer risks of 10^{-6}, 10^{-5}, and 10^{-4}. Therefore, multiple HHPRGs are calculated for a given receptor and medium. By providing multiple HHPRGs for a single medium, risk managers have at their disposal a range of possible risk-based cleanup levels. The range of options provides flexibility when considering the remedial alternatives from one exposure unit at SLDS to another. For example, selection of a lower health-based target may be warranted if there are multiple constituents present and additivity of effects is of concern. Alternatively, a higher target may be selected if the exposure assumptions are believed to be overly conservative, if there are very few PCOCs, or if the health effects to multiple constituents are not believed to be additive. The selection of the final remediation levels is made by the risk managers and will be presented in the ROD for SLDS. The final remediation assures compliance with CERCLA 10^{-4} to 10^{-6} risk criteria when the total residual risk from MED/AEC radiological and non-radiological PCOCs are considered. The following sections summarize the selection of PCOCs and the calculation of HHPRGs.

2.6.2 Selection of Chemical HHPRGs

Chemical HHPRGs were developed for each of the PCOCs presented in the baseline risk assessment for soil and groundwater. The PRGs presented are intended to protect for future industrial land, as is appropriate for SLDS. The EPA usually requires a residential scenario in baseline risk assessments, even though it is not the most likely future use of the site. This is typically included as a point of comparison for decision-makers. The default assumptions used in the baseline risk assessment provide a common frame of reference that may be compared to other similar sites. Because SLDS has been heavily industrialized for more than 100 years, residential conversion of the land is considered to be highly unlikely. For the purpose of deriving HHPRGs for SLDS (ie, in the FS), an industrial setting is believed to represent the only plausible land use at SLDS. The industrial scenario used for derivation of HHPRGs at SLDS is based on likely future industrial exposures as assessed by Mallinckrodt. Detailed information on exposure and intake parameters used for derivation of HHPRGs is provided in Appendix C.

2.6.3 Derivation of Chemical HHPRGs

In the following section, HHPRGs will be determined for PCOCs in soil and groundwater. The calculations of HHPRGs use EPA-approved toxicity values and exposure assumptions from the baseline human health risk assessment. HHPRGs are determined using multiple noncancer target hazard quotients (ie, 0.1, 1, and 3) and target cancer risks (ie, 10^{-6}, 10^{-5}, and 10^{-4}). Therefore, two different equations are needed to calculate HHPRGs.

Table 2-15 presents the HHPRGs for soil and groundwater. In situations where both noncarcinogenic and carcinogenic toxicity values are available, HHPRGs are calculated using both values. For a given target hazard index and target cancer risk, the most restrictive appropriate HHPRG (ie, based on either noncancer or cancer targets) is usually selected. Exposure assumptions used to calculate the HHPRGs are selected to be as consistent as possible with those used to derive the guidelines for cleanup of radionuclides at SLDS. HHPRGs for chemicals have been calculated using the following exposure assumptions:

- An adult worker at the workplace
  - 250 days/year (as used for radionuclide guidelines)
  - 25 years (as used for radionuclide guidelines)
  - 70 kg body weight

- Incidental exposures to groundwater and soil considered
  - Oral ingestion of soil: 136 mg/day (as used for radionuclide guidelines; 49.64g/yr × yr/365days × 1000mg/g)
  - Dermal contact with soil: 5,800 cm^2 exposed skin surface area (arms and hands)
  - Inhalation of dust emitted from soil:
    - 28.9 m^3/day (as used for radionuclide guidelines; 10,550 m^3/yr × yr/365days)
    - Particulate emission factor is 5×10^6 m^3/kg (converted from that used for radionuclide guidelines; $(0.0002\ g/m^3 \times kg/1000\ g)^{-1} = 5 \times 10^6\ m^3/kg$
  - No oral ingestion of groundwater (0 L/day)
  - Dermal contact with process water: 5,800 cm^2 exposed skin surface area (arms and hands)
  - Inhalation of vapors emitted from groundwater (ie, process water): 28.9 m^3/day (as used for radionuclide guidelines)

  - Volatilization factor (K) is 0.5 L/m^3 (EPA 1991a)
    - Simple approach
    - Accounts for multiple sources of indoor vapors

The HHPRGs for soil take into account the combined effect of exposure across the ingestion, dermal, and inhalation pathways, whereas for groundwater they account for dermal contact and

Table 2-15. Prelimary Remediation Goals for Industrial/Construction Workers in the Workplace: St. Louis Downtown Site

	Toxicity Value								Risk-Based PRGs					
	RfD			CSF			Target		Soil (mg/kg)			Groundwater (ug/L)		
Chemical	Oral	Dermal	Inhalation	Oral	Dermal	Inhalation	Hazard Quotient	Cancer Risk	Noncarcinogenic Effects	Carcinogenic Effects	Lower	Noncarcinogenic Effects	Carcinogenic Effects	Lower
INORGANICS														
Arsenic	3.0E-04	3.0E-04	--	1.5E+00	3.7E+00	1.5E+01	0.1	1E-06	5.7	0.31	0.31	529	13	13
Cadmium (food or solid)	1.0E-03	1.0E-05	5.7E-05	--	--	6.3E+00	0.1	1E-06	1.6	10,515	1.6	--	--	--
Cadmium (water)	5.0E-04	5.0E-06	5.7E-05	--	--	6.3E+00	0.1	1E-06	--	--	--	8.8	No CSF	9
Copper	4.0E-02	4.0E-02	--	--	--	--	0.1	1E-06	760	No CSF	760	70,483	No CSF	70,483
Nickel	2.0E-02	2.0E-02	--	--	--	--	0.1	1E-06	380	No CSF	380	35,241	No CSF	35,241
Uranium	3.0E-03	3.0E-03	--	--	--	--	0.1	1E-06	57	No CSF	57	5,286	No CSF	5,286

	Toxicity Value								Risk-Based PRGs					
	RfD			CSF			Target		Soil (mg/kg)			Groundwater (ug/L)		
Chemical	Oral	Dermal	Inhalation	Oral	Dermal	Inhalation	Hazard Quotient	Cancer Risk	Noncarcinogenic Effects	Carcinogenic Effects	Lower	Noncarcinogenic Effects	Carcinogenic Effects	Lower
INORGANICS														
Arsenic	3.0E-04	3.0E-04	--	1.5E+00	3.7E+00	1.5E+01	1	1E-05	57	3.07	3.1	5,286	135	135
Cadmium (food or solid)	1.0E-03	1.0E-05	5.7E-05	--	--	6.3E+00	1	1E-05	16	105,152	16	--	--	--
Cadmium (water)	5.0E-04	5.0E-06	5.7E-05	--	--	6.3E+00	1	1E-05	--	--	--	88	No CSF	88
Copper	4.0E-02	4.0E-02	--	--	--	--	1	1E-05	7,599	No CSF	7,599	704,828	No CSF	704,828
Nickel	2.0E-02	2.0E-02	--	--	--	--	1	1E-05	3,799	No CSF	3,799	352,414	No CSF	352,414
Uranium	3.0E-03	3.0E-03	--	--	--	--	0.1	1E-06	57	No CSF	57	5,286	No CSF	5,286

	Toxicity Value								Risk-Based PRGs					
	RfD			CSF			Target		Soil (mg/kg)			Groundwater (ug/L)		
Chemical	Oral	Dermal	Inhalation	Oral	Dermal	Inhalation	Hazard Quotient	Cancer Risk	Noncarcinogenic Effects	Carcinogenic Effects	Lower	Noncarcinogenic Effects	Carcinogenic Effects	Lower
INORGANICS														
Arsenic	3.0E-04	3.0E-04	--	1.5E+00	3.7E+00	1.5E+01	3	1E-04	171	31	31	15,859	1,349	1,349
Cadmium (food or solid)	1.0E-03	1.0E-05	5.7E-05	--	--	6.3E+00	3	1E-04	49	1,051,524	49	--	--	--
Cadmium (water)	5.0E-04	5.0E-06	5.7E-05	--	--	6.3E+00	3	1E-04	--	--	--	--	--	--
Copper	4.0E-02	4.0E-02	--	--	--	--	3	1E-04	22,796	No CSF	22,796	2,114,483	No CSF	2,114,483
Nickel	2.0E-02	2.0E-02	--	--	--	--	3	1E-04	--	--	--	1,057,241	No CSF	1,057,241
Uranium	3.0E-03	3.0E-03	--	--	--	--	0.1	1E-06	57	No CSF	57	5,286	No CSF	5,286

PRG is the lesser of the noncarcinogenic or carcinogenic PRG.
Noncancer effects based on chronic toxicity.
Toxicity values published by EPA (EPA 1995a, EPA 1997a)
  EPA IRIS Data Base (November 1997).
  USEPA ORD Health Effects Assessment Summary Tables (HEAST) FY 1997 Update (July).
For copper, the EPA Office of Drinking Water MCL of 1.3 mg/L has been converted to intake estimate of 3.7E-02 mg/kg-day by assuming ingestion of 2 liters of water/day by a 70 kg adult.
Soil exposures include ingestion, dermal contact, and inhalation of dust.
Groundwater exposures include dermal contact and inhalation of volatilized organics; there is no ingestion exposure assumed for this groundwater.
Exposure to volatilized organics includes numerous indoor sources, as provided by "K" in equation 1 of RAGS Part B 1991.
Provisional CSF from EPA NCEA-SHRTSC applied for trichloroethylene
Provisional RfD from EPA NCEA-SHRTSC applied for trichloroethylene
-- Substance is not a COC for this medium

inhalation exposure. This is indicated in the equations used to derive the HHPRGs. The equation used to calculate HHPRGs for soil exposures based on noncancer effects is as follows:

$$PRG = \frac{THQ \times BW \times AT \times 365\ \text{days/year}}{ED \times EF\ [(1/RfD_i \times VR \times 1/PEF) + CF\ [(1/RfD_o \times IR) + (1/RfD_d \times SA \times AF \times ABS)]]}$$

where:
ABS = Absorption factor for skin (unitless)
AF = Adherence factor for soil on skin (mg/cm^2)
AT = Averaging time for noncancer effects (years)
BW = Body weight (kg)
CF = Conversion factor (1×10^{-6} kg/mg)
ED = Exposure duration (years)
EF = Exposure frequency (days/year)
IR = Soil ingestion rate (mg/day)
PEF = Particulate emission Factor (m^3/kg)
PRG = Preliminary remediation goal for soil (mg/kg)
RfD_d = Reference dose, dermal (mg/kg-day)
RfD_i = Reference dose, inhalation (mg/kg-day)
RfD_o = Reference dose, oral (mg/kg-day)
SA = Exposed skin surface area (cm^2/day)
THQ = Target hazard quotient (unitless)
VR = Ventilation rate (m^3/day)

For cancer effects, the equation used to calculate HHPRGs for soil exposures is as follows:

$$PRG = \frac{THQ \times BW \times AT \times 365\ \text{days/year}}{ED \times EF\ [(CSF_i \times VR \times 1/PEF) + CF\ [(CSF_o \times IR) + (CSF_d \times SA \times AF \times ABS)]]}$$

where:
ABS = Absorption factor for skin (unitless)
AF = Adherence factor for soil on skin (mg/cm^2)
AT = Averaging time for cancer effects (years)
BW = Body weight (kg)
CF = Conversion factor (kg/mg)
CSF_d = Cancer slope factor, dermal (1/(mg/kg-day))
CSF_i = Cancer slope factor, inhalation (1/(mg/kg-day))
CSF_o = Cancer slope factor, oral (1/(mg/kg-day))
ED = Exposure duration (years)
EF = Exposure frequency (days/year)
IR = Soil ingestion rate (mg/day)
PEF = Particulate emission Rate (m^3/kg)
PRG = Preliminary remediation goal for soil (mg/kg)
SA = Exposed skin surface area (cm^2/day)
TCR = Target cancer risk (unitless)
VR = Ventilation rate (m^3/day)

The equation used to calculate HHPRGs for groundwater exposures based on noncancer effects is as follows:

$$PRG = \frac{THQ \times BW \times AT}{EF \times ED \times CF_A\ [(1/RfD_i \times K \times VR) + (1/RfD_o \times IR) + (1/RfD_d \times SA \times PC \times CF_B \times ET)]}$$

where:
AT = Averaging Time for noncancer effects (days)
BW = Body Weight (kg)
CF_A = Conversion factor (mg/g)
CF_B = Conversion factor (L/cm^3)
ED = Exposure Duration (years)
EF = Exposure Frequency (days/year)
IR_o = Oral Ingestion Rate (L/day)
K = Volatilization Factor (L/m^3)
PC = Permeability Coefficient, dermal (chemical-specific; mg/kg-day)
PRG = Preliminary remediation goal for Groundwater (g/L)
RfD_d = Reference Dose, dermal (chemical-specific; mg/kg-day)
RfD_i = Reference Dose, inhalation (chemical-specific;mg/kg-day)
RfD_o = Reference Dose, oral (chemical-specific; mg/kg-day)
SA = Surface Area, dermal (cm^2)
THQ = Target Hazard Quotient (unitless)
VR = Ventilation Rate (m^3/day)

For cancer effects, the equation used to calculate HHPRGs for groundwater is as follows:

$$PRG = \frac{TCR \times BW \times AT}{ED \times EF \times CF_A\,(CSF_i \times K \times VR) + [(CSF_o \times IR_o) + CF\,(CSF_d \times SA \times PC \times CF_B \times ET)]}$$

where:

AT = Averaging Time for noncancer effects (days)
BW = Body Weight (kg)
CF_A = Conversion factor (mg/g)
CF_B = Conversion factor (L/cm^3)
CSF_d = Cancer Slope Factor, dermal (mg/kg-day)$^{-1}$
CSF_i = Cancer Slope Factor, inhalation (mg/kg-day)$^{-1}$
CSF_o = Cancer Slope Factor, oral (mg/kg-day)$^{-1}$
ED = Exposure Duration (years)
EF = Exposure Frequency (days/year)
ET = Exposure Time (hour/day)
IR_o = Oral Ingestion Rate (L/day)
K = Volatilization Factor (L/m^3)
PC = Permeability Coefficient, dermal (chemical-specific, cm/hour)
PRG = Remedial Goal Option for Groundwater (mg/L)
SA = Surface Area, dermal (cm^2)
TCR = Target Cancer Risk (unitless)
VR = Ventilation Rate (m^3/day)

Toxicity information is obtained primarily from the Integrated Risk Information System (EPA 1997a), and secondarily from the Health Effects Assessment Summary Tables (EPA 1997b). Provisional toxicity values are obtained from the Superfund Health Risk Technical Support Center - National Center for Environmental Assessment of EPA (SHRTSC-NCEA). Provisional values are the least preferable of the three sources cited. In cases where no toxicity value is available, surrogate toxicity values have been applied. EPA does not provide verified toxicity values for TCE.

Provisional toxicity values are, however, available from EPA (SHRTSC-NCEA) for TCE, and the provisional value has been used in deriving the toxicity values.

2.6.4 Radiological PRGs

PRGs for the radiological PCOCs at SLDS have been determined using methods essentially equivalent to those described above for the chemical PCOCs. Table 2-16 provides a summary of PRGs for the radiological PCOCs, and Appendix C contains details of the exposure scenarios and assumptions used for the PRG calculations. In general, the radiological PRGs are back calculated using methods similar to the chemical PRGs, with the exception that dermal exposures and inhalation of volatile contaminants are not included in the PRG calculation. Dermal exposure is not included since it is a very minor pathway for radiological exposures, and radon (the only potential volatile radionuclide of concern) is considered separately using a concentration limit as part of the assessment in Appendix C.

2.7 PREVIOUS REMOVAL ACTIONS

In the course of implementing a comprehensive cleanup strategy, DOE determined that soils and numerous structures across SLDS were impacted above DOE guidelines for radioactivity. DOE recognized that many operational and maintenance activities conducted by site proprietors could result in the generation of impacted materials and lead to the inadvertent spread of and exposure to

Table 2-16. Preliminary Remediation Goals for Potential Radionuclides of Concern in SLDS Soils Based on a Long-Term Worker (Industrial/Construction) Scenario

Radionuclide	Cancer Risk			
	1×10^{-6}	1×10^{-5}	1×10^{-4}	3×10^{-4} [(a)]
	PRG Concentration (pCi/g)			
Ac-227	0.2	2	21	64
Pa-231	0.2	2	22	65
Ra-226+D	<BKG	<BKG	4	11
Th-230	<BKG	<BKG	10	30
Th-232+D	<BKG	<BKG	3	7.6
U-235	0.8	8	80	239
U-238+D	2.6	26	262	787

Notes:

1. Exposure and intake parameters are based on Mallinckrodt site-specific assumptions and references as shown in Appendix C.
2. PRG calculations include contributions from decay and ingrowth of radioactive progeny to 1,000 yrs. The most limiting value for each decay chain is shown (ie, Th-232 includes the contributions from Ra-228, Th-228, and other progeny, and the PRG is based on the most limiting concentration in this decay series).
3. <BKG indicates that the calculated PRG value is less than background for St. Louis site soils. Background values are based on the St. Louis Site RI (BNI 1994a) and include 0.9 pCi/g Ra-226, 1.3 pCi/g Th-230, 1.0 pCi/g Th-232 (also Ra-228 and Th-228), and 1.1 pCi/g U-238 (also U-234). U-235 background is estimated as 4.6% of U-238 (0.05 pCi/g), and Ac-227 and Pa-231 are assumed to have background concentrations equal to U-235.

[(a)] EPA risk assessment guidance indicates that PRGs are typically summarized for risks ranging from 10^{-6} to 10^{-4}. However, OSWER Directive 9200.4-18 specifically indicates that 3×10^{-4} is considered protective and consistent with regulations and guidance developed by EPA in other radiation control programs.

D = daughters

these materials. DOE prepared the EE/CA for Decontamination at the St. Louis Downtown Site, St. Louis, Missouri, May 1991, DOE/OR/23701-02.2, to address removal actions to minimize inadvertent exposure to impacted materials and allow for the consolidation of the resultant impacted materials at engineered interim storage areas within the site. The specific objectives were as follows:

- Support the SLDS proprietors in the performance of plant activities involving movement or displacement of impacted materials,
- Waste minimization through segregation and/or decontamination,
- Consolidation of impacted materials in indoor or outdoor controlled areas,
- Minimization of potential health hazards to on-site personnel performing activities, and
- Collection and analysis of soil samples taken after the response action was implemented to confirm that decontaminated areas met applicable guidelines.

The preferred alternative included consolidation of impacted waste from site activities (ie, structural materials and soil) and placement into controlled interim storage areas at SLDS.

The alternatives in the EE/CA described above considered the use of an off-site disposal facility. Off-site disposal was not feasible at that time due to the lack of a permitted, cost-effective disposal site. A commercial disposal facility has been approved to accept waste of this type since the SLDS EE/CA was finalized. Excavated soils have been sent off-site for disposal.

Four interim actions have been performed at SLDS in accordance with the provisions of the EE/CA. These actions are summarized in Table 2-17.

Table 2-17. Interim Actions at SLDS Since April 1994

Property	Remedy	Volumes Remediated*	Authorizing Document
50 Series Buildings (Bldgs. 50, 51, 51A, 52, and 52A)	Decontamination, demolition, and crushing	1,000 yd^3 shipped off-site; 1,000 yd^3 of crushate stockpiled in a fenced area on Mallinckrodt Inc. property	DOE/OR/23701-02.2
Plant 6 and 7 Buildings (Bldgs. 100, 116, 116B, 117, 700, 704, 705, 706, 707, and 708)	Asbestos abatement, decontamination, demolition to floor elevation grade, crushing	2,673 yd^3 shipped off-site; 7,000 yd^3 of crushate stockpiled on the Mallinckrodt Inc. property, Lot 7E	DOE/OR/23701-02.2
Plant 10 area subsurface soil	Excavation	15,043 yd^3 shipped off-site	DOE/OR/23701-02.2
City Property (Riverfront Trail area)	Excavation	750 yd^3 shipped off-site	DOE/OR/23701-02.2

* These are the volumes shipped. They are greater than the in situ impacted volumes because they include any extra soil to assure removal and the bulking (volume increase) that results from excavation.

In FY 95, 15,043 yd^3 of impacted soil was excavated from the Mallinckrodt Inc. Plant 10 area and shipped off-site.

In 1996, 750 yd^3 of impacted soil was excavated from the City Property, Riverfront Trail area, and shipped off-site.

The 50 Series Buildings on the Mallinckrodt Inc. property were decontaminated and demolished also during FY 96. The masonry rubble from the demolition was processed through a rock crusher in order to reduce the volume and to apply volumetric criteria to the crushed masonry (crushate). Approximately 1,000 yd^3 of crushate was generated and is stored in a covered pile, located in a fenced area on Mallinckrodt Inc. Property. Samples of the crushate were analyzed and found to be near background. The noncrushable materials (1,000 yd^3) were shipped off-site.

During FY 97, an interim action was conducted on the Plant 6 and 7 Buildings (Buildings 100, 116, 116B, 117, 700, 704, 705, 706, 707, and 708) at the Mallinckrodt Inc. property.

The interim action consisted of removing the asbestos located within the buildings, performing minor decontamination, and demolishing the buildings. Similar to the 50 Series Buildings, the masonry rubble from the demolition was processed through a rock crusher to reduce the volume and to apply volumetric criteria to the crushate. Approximately 7,000 yd^3 of crushate was generated and is stored in a pile on Lot 7E on the Mallinckrodt Inc. property. Samples of the crushate were analyzed and found to be well below radiological criteria. The noncrushable material and asbestos (approximately 2,673 yd^3) was shipped off-site.

3. IDENTIFICATION AND SCREENING OF REMEDIAL ACTION TECHNOLOGIES

Figure 3-1 illustrates the FS process. This section focuses on the identification and formulation of remedial action objectives, identification of general response actions (GRAs), and identification and evaluation of remedial action technologies. The technologies remaining after screening and evaluation were used to develop remedial action alternatives (Section 4).

3.1 INTRODUCTION

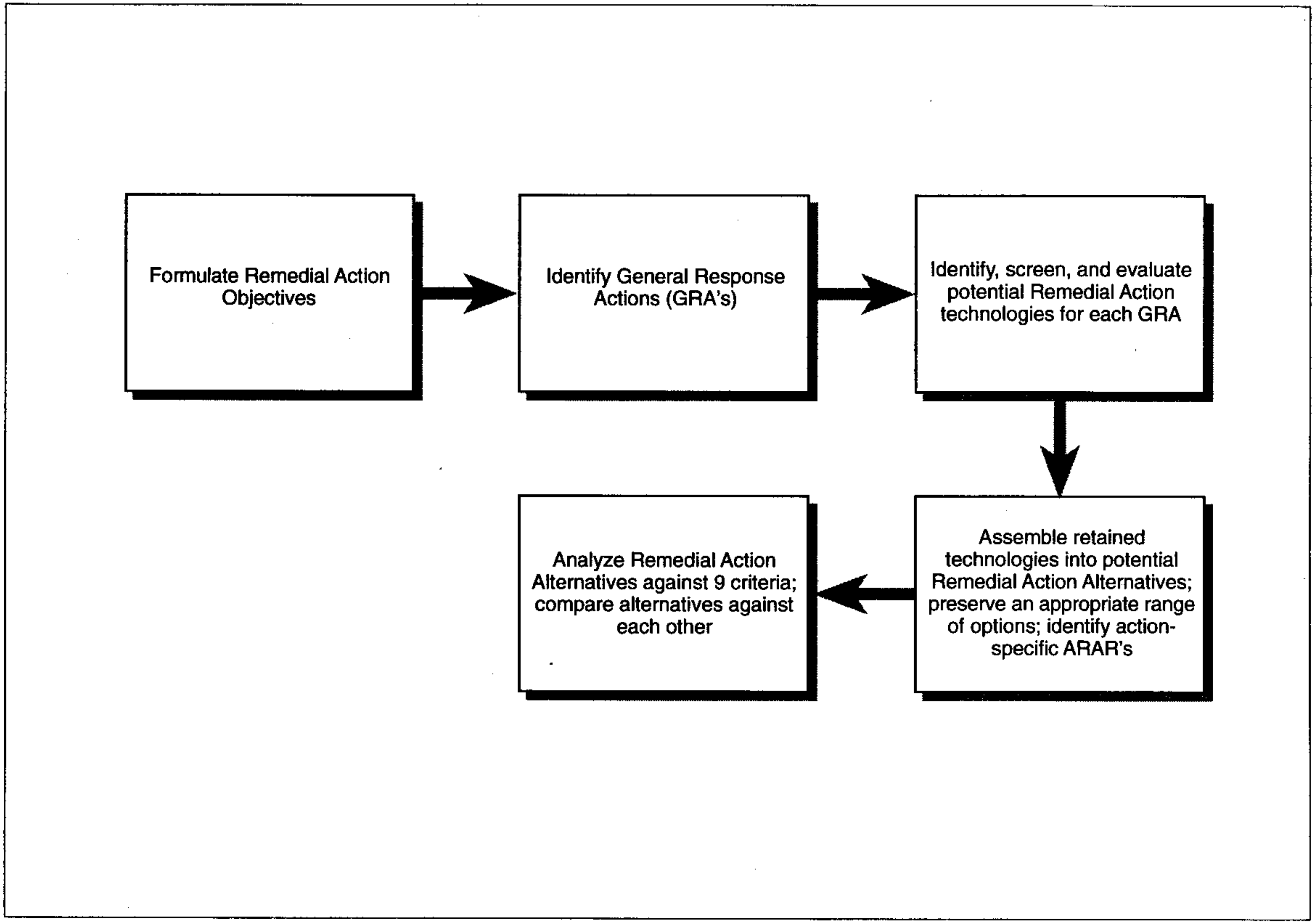
The purpose of Phase I of the FS process is to identify potential remedial action technologies that can be assembled into remedial action alternatives. This process involves the following steps:

- Identifying preliminary remedial action objectives specific to the contaminated environmental media or remedial units;
- Identifying general response actions (eg, removal, treatment, and disposal) required to attain the remedial action objectives and cover the scope of possible remediation activities for the affected sites;
- Identifying remedial action technologies (eg, physical processes) that can be applied for each of the general response actions, and performing an initial screening to reduce the number of these options for further evaluation; and
- Combining retained technologies into potential remedial action alternatives and evaluating them on the basis of effectiveness, implementability, and cost.

In addressing these four steps, the results of the initial screening of alternatives (ISA) study (SAIC 1992) have been incorporated. Section 3.2 develops remedial action objectives for each medium of interest, identifies ARARs, and identifies likely exposure routes and receptors. Section 3.3 identifies general response actions that satisfy remedial action objectives for each medium of interest at the site. Section 3.4 presents a summary of retained remedial action technologies that address contaminated media at SLDS.

3.2 REMEDIAL ACTION OBJECTIVES

Remedial action objectives developed in this FS provide the basis for proposed remedial actions at the St. Louis site. They are based on the nature and extent of contamination, threatened resources, and the potential for human and environmental exposure.



FUS St. Louis 01/98

Figure 3-1. Schematic Representation of the Feasibility Study Process

EPA specifies two threshold criteria for evaluating potential remedial action alternatives (EPA 1989a):

- Overall protection of human health and the environment, and
- Compliance with ARARs.

Alternatives for site remediation must comply with ARARs, but the application of single chemical ARARs may not be sufficiently protective where there are multiple chemicals present and/or multiple exposure pathways present. ARARs may not exist for a specific chemical or pathway of concern, and site-specific factors such as multiple chemicals and multiple exposure pathways may result in unacceptable residual cumulative risk. As a result, a cleanup level set at the level of a single contaminant-specific requirement may not adequately protect human health or the environment. It may, therefore, be necessary to develop risk-based remediation goals using site-specific information.

EPA guidance requires that remedial alternatives be developed that protect human health and the environment by controlling, reducing, or eliminating risks at the site. Remedial alternative formulation is a phased process consisting of the steps described below.

The first step in formulating remedial alternatives is to identify remedial action objectives specifying media and PCOCs, potential exposure pathways, and preliminary remediation goals. The goals are defined in terms of risk-based exposure levels that are protective of human health and the environment and are developed by considering ARARs and the following factors [see 1990 NCP at Section 300.430(e)(2)(i)]:

- For noncarcinogenic toxicants, acceptable exposure levels are those concentrations that the most susceptible human population may be exposed to over a lifetime without adverse effects. The EPA hazard index is a measure of the potential for adverse non-carcinogenic health effects due to exposure to site-related chemicals. A hazard index of one or greater indicates that there may be a concern for non-carcinogenic effects associated with exposure to site-related chemicals.

- For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper-bound lifetime cancer risk to an individual of between 10^{-6} to 10^{-4} using information on the relationship between dose and response. This range is intended to provide case-by-case flexibility, although the 10^{-6} risk level is the point of departure for determining goals for alternatives when ARARs are unavailable or not sufficiently protective. While 10^{-6} is considered the point of departure for developing remediation goals, EPA has recently provided specific guidance (OSWER Directive 9200.4-18) with regard to developing cleanup guidelines for radionuclides. This guidance and previous EPA directives such as OSWER Directive 9200.4-18 indicate that the upper boundary of the risk range is not a discrete line at 10^{-4}, and that a specific risk estimate around 10^{-4} may be considered acceptable if justified based on site specific conditions. For radionuclides, risk estimates of up to 3×10^{-4} have been considered protective.

- Land use should be considered in risk assessment and remedy selection by involving the community, considering the context of the site, and determining the site's potential for reuse (EPA 1995). An assumption of a land use other than residential (eg, industrial) would be appropriate in remedy selection at SLDS.

- In the case of multiple contaminants, where the attainment of ARARs will result in a cumulative risk in excess of 10^{-4}, alternate risk based remediation goals must be developed to reduce risk within the acceptable range.

- Water Quality Criteria (WQC) are non-enforceable guidance and can be ARARs, depending upon the designated uses of the water and the purposes for which potential requirements are intended. WQC established under Sections 303 and 304 of the Clean Water Act (CWA) shall be attained if relevant and appropriate.

- An alternate concentration limit may be established in accordance with CERCLA Section 121(d)(2)(B)(ii).

- Environmental evaluations shall be performed to assess threats to the environment, especially sensitive and critical habitats of species protected under the Endangered Species Act (ESA).

- Other factors may be related to technical limitations, uncertainty, and other pertinent information.

A requirement under federal and state environmental laws may be classified applicable or relevant and appropriate, but not both. Identifying ARARs is a two-step process that determines whether the requirement is applicable and, if not, whether it is both relevant and appropriate. Site-specific factors used to identify ARARs include the physical circumstances of the site, contaminants present, and characteristics of the remedial action. These factors are compared to the requirement under evaluation to determine whether it is directly applicable or relevant and appropriate. The terms are defined in the 1990 NCP (Section 300.5) as follows.

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site. Only those state requirements that are (1) promulgated so that they are of general applicability and legally enforceable, (2) identified by a state in a timely manner, and (3) are more stringent than federal requirements are applicable.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental or facility siting laws that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is suited to the particular site. Thus, according to EPA, a requirement may be determined to be relevant and appropriate if the established health or environmental limit is based on an exposure scenario similar to the potential exposure at a CERCLA site (FR 1990). EPA considers this the focal point for determining if a requirement is relevant and appropriate. Where state environmental standards have been promulgated to enact more stringent standards than are required by federal regulations, including EPA, those state standards may be ARARs [42 USC §9621(d)(2)(A)(ii) (1992, as amended)]. The availability of numerical values for these standards varies widely from state to state.

According to CERCLA guidance (EPA 1988b), in comparing the requirement and the site circumstances or the circumstances of the release, some of the following factors and related considerations might be particularly important in determining whether a requirement is appropriate:

- the purpose of the requirement;
- the physical characteristics (size/nature) of the site and contamination;
- the character and circumstances of the release at the site compared to what the requirement was intended to address and requires;
- the substances covered by the requirement (eg, the chemical characteristics, form, or concentration of the contamination or release for which the requirement was designed);
- the duration of the activity; and,
- the basis for a waiver or exemption.

In addition, one should consider:

- whether another requirement is available that more fully matches the circumstances at the site; and
- where EPA has explicitly decided that a requirement is not appropriate to a situation, that requirement will not be appropriate for such a situation at a CERCLA site.

According to NCP requirements [40 CFR 300.400(g)(4)] on evaluating relevance and appropriateness, the following factors shall be examined, where pertinent, to determine whether a requirement addresses problems or situations sufficiently similar to the circumstances of the release or remedial action contemplated, and whether the requirement is well-suited to the site, and therefore is both relevant and appropriate.

- the purpose of the requirement and the purpose of the CERCLA action;
- the medium regulated or affected by the requirement and the medium contaminated or affected at the CERCLA site;

- the substances regulated by the requirement and the substances found at the CERCLA site;

- the actions or activities regulated by the requirement and the remedial action contemplated at the CERCLA site;

- any variances, waivers, or exemptions of the requirement and their availability for the circumstances at the CERCLA site;

- the type of place regulated and the type of place affected by the release or CERCLA action;

- the type and size of structure or facility regulated and the type and size of structure or facility affected by the release or contemplated by the CERCLA action; and

- any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resource at the CERCLA site.

The pertinence of each of these factors will depend, in part, on whether a requirement addresses a chemical, location, or action.

In accordance with EPA guidance on ARARs, only applicable requirements are evaluated for off-site actions, whereas both applicable and relevant and appropriate requirements are evaluated for onsite actions. Onsite actions must comply with a requirement that is determined to be relevant and appropriate as well as one that is determined to be applicable. However, a determination of relevance and appropriateness may be applied to only portions of a requirement, whereas a determination of applicability is made for the requirement as a whole.

Onsite actions must comply with substantive requirements of ARARs but not with related administrative and procedural requirements. For example, remedial actions conducted onsite would not require a permit but would be conducted in a manner consistent with the permitted conditions. The application of specific environmental regulations to activities being considered for off-site facilities, such as disposal of waste at a commercial disposal facility, would be addressed by the respective owners/operators in the environmental compliance documents and activities for those facilities.

A third classification of standards, requirements, criteria or limitations is "to be considered" (TBC). A TBC standard is a non-promulgated advisory or guidance that is not legally binding and does not have the legal status of a potential ARAR. If no other standard is available, that is, there is no specific ARAR for a situation to help determine the necessary level of cleanup for protection of health or the environment, a TBC can be used as guidance and included along with ARARs. DoD Directives, Army Regulations (ARs), and Engineer Regulations (ERs) that are not also promulgated as regulations will be treated as TBC under CERCLA. Even when DoD directives, ARs, and ERs are not promulgated as regulations, DoD/USACE activities still must comply with them, so they are a special class of TBCs.

Regardless of whether a requirement is applicable or relevant and appropriate, CERCLA §121 stipulates compliance with all ARARs established by federal law and, where they are more stringent, state laws, unless the situation is suitable for an ARAR waiver to apply. Section 121(d)(4) of CERCLA identifies six circumstances under which ARARs may be waived:

- The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement.
- Compliance with a requirement will result in greater risk to human health and the environment than other alternatives.
- Compliance with a requirement is technically impracticable from an engineering perspective.
- The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach.
- The ARAR is a state requirement that the state has neither consistently applied, nor demonstrated the intention to consistently apply the promulgated requirement in similar circumstances at other remedial actions within the state.
- For Fund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund monies to respond to other sites that may present a threat to human health and the environment.

DoD and USACE policies, directives, and regulations do not contain additional or alternative waiver provisions, but rather direct that DoD/USACE comply with CERCLA requirements.

3.2.1 Preliminary Identification of ARARs

CERCLA directs that remedial actions at NPL sites, and removal actions to the extent practicable, must comply with the ARAR requirements of environmental laws. CERCLA response actions must also comply with employee protection laws such as OSHA Standards/Occupational Health and Environmental Control.

3.2.1.1 Chemical-Specific ARARs

Chemical-specific ARARs are the primary category for SLDS. Chemical-specific ARARs are health- or risk-based numerical values that, when applied to site-specific conditions, can be used to formulate remedial action objectives. These values reflect the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment without harm to human health or safety. When determining cleanup level criteria, attainment of chemical-specific ARARs is allowed by the NCP [300.430 (e)(2)(A and D)]. If a chemical has more than one ARAR, then the most stringent generally should apply.

Appendix A summarizes the potential ARARs for radionuclides and chemicals detected in soils and structures.

Soils

Currently, there are a limited number of promulgated chemical-specific ARARs for soils. As discussed below, management of the soils in accordance with relevant and appropriate portions of 10 CFR 20 Subpart E, 40 CFR 192, and USEPA Guidance will ensure protection of human health and the environment from radiological contamination. In addition, disposal of the soil in accordance with either 40 CFR 258 or 40 CFR 262, 264, and 268 and their corresponding state requirements will ensure protection of human health and the environment for non-radiological contamination. Worker protection will be attained during remediation by complying with OSHA regulations and DoD/USACE policies.

Some ARARs specifically address radionuclides in soil. The primary agencies with regulatory authority for the cleanup of radioactively contaminated sites include EPA and NRC. In general, determination of an ARAR for a site contaminated with radioactive materials requires consideration of the radioactive constituents present and the functional operations that occur at the site, whose regulatory jurisdiction the site falls under, and which regulation is most protective (EPA 1989a).

EPA's regulatory authority for radioactively contaminated sites is derived from several statutes including the Atomic Energy Act, the Clean Air Act (CAA), the Uranium Mill Tailings Radiation Control Act (UMTRCA), and CERCLA. Implementation and enforcement responsibilities for many EPA standards are vested in other agencies, including DoD/USACE (EPA 1989a). Although many states have their own authority and regulations for managing radioactive material and waste, the State of Missouri has not implemented regulations that address radioactive contamination in soil.

The USACE has authority for conducting or overseeing environmental restoration activities at numerous government facilities, and now has authority for FUSRAP sites containing radioactive waste. At least three other programs administered by the USACE address radioactive waste as well as chemical and biological waste. The USACE is authorized under CERCLA to manage all hazardous substances, including radioactive materials.

With regard to cleanup standards and requirements, DoD/USACE must follow the requirements of CERCLA. Potential ARAR guidance for cleanup standards under CERCLA are the NRC rules for decontamination and decommissioning at 10 CFR 20 Subpart E; USEPA OSWER Directive No. 9200.4-18, *Cleanup Levels for CERCLA Sites with Radioactive Contamination*, August 22, 1997; and 40 CFR Section 192. 40 CFR 192 establishes radiological protection requirements and guidelines for remediating residual radioactive material, management of the resulting wastes and residues, and release of property. Both the NRC requirements and 40 CFR 192 are relevant and appropriate to the cleanup of FUSRAP sites. Discussed below are some guidelines for permissible dose limits and derivations for acceptable soil remediation levels.

40 CFR 192 includes residual contamination guidelines that provide a concentration action level for radioactive contaminants of radium (Ra-226 and Ra-228) in soil. As shown in Table 3-1, the action level for surface soil is 5 pCi/g above background when averaged over the first 15 cm (6 in) by 100 m^2 (120 yd^2) area, and the action level for subsurface soils is 15 pCi/g above background when averaged below 15 cm (6 in) of the surface in 15 cm (6 in) depths by 100 m^2 (120 yd^2) surface area.

The uranium action levels were developed on a site-specific basis. The limits are 50 pCi/g above background for U-238 and 100 pCi/g above background for total uranium where the same 15 cm (6 in) depth by 100 m^2 (120 yd^2) surface area volume consideration applies as in 40 CFR 192 (Fiore 1990). The uranium guideline was developed in accordance with Federal Guidance as outlined in Table 3-1. DOE Orders are not generally applicable to actions implemented by USACE, but are classified as TBC guidance. 10 CFR 20 specifies that members of the public will not receive an annual dose in excess of 100 mrem effective dose equivalent from any operation or facility. Table 3-1 summarizes these requirements.

In addition to these radiation protection standards, NRC mandates that exposures and releases of radioactive materials to the environment be restricted to a level that is as low as reasonably achievable (ALARA). The ALARA principle has as its objective the attainment of dose levels as far below the applicable limits required by ARARs as practicable, taking into consideration public policy, technical limitations, economic feasibility, and practicality.

UMTRCA directed EPA to set standards governing the stabilization, disposal, and control of uranium and thorium mill tailings. These standards have been promulgated in 40 CFR 192. Requirements under 40 CFR 192 do not specifically address SLDS and are, therefore, not applicable; however, circumstances at SLDS are sufficiently similar to inactive uranium processing sites designated under Section 102 of UMTRCA to warrant several sections of 40 CFR 192 being relevant and appropriate. Therefore, while the 40 CFR 192 Subpart B standards are directly applicable only to the inactive uranium processing sites specifically designated under Title I of UMTRCA, they are relevant and appropriate for SLDS. Conditions at SLDS are not significantly different from those at the uranium mill sites for which the 40 CFR 192 standards were developed. Both the St. Louis sites and the sites managed under UMTRCA are the result of radioactive ore processing activities, and include numerous "vicinity properties" impacted by relocation of radioactive materials by erosion, use of radioactive materials as fill material, and spillage during transportation. Both programs address identical contaminants of concern at sites characterized by large volumes of impacted soil, widely ranging soil radionuclide concentrations, and land use ranging from residential to industrial. The distribution of radioactive materials at SLDS is very similar to that at uranium mill tailings sites. Radioactive materials which eroded and were windblown from the site or spilled during transport are spread in thin layers, much the same as the windblown tailings at some uranium mill sites. The tailings that were removed at the uranium mill sites were the sand fractions which typically have radium concentrations of less than 100 pCi/g, also similar to the materials at St. Louis.

Table 3-1. Summary of Radiological Residual Contamination Guidelines for Soils and Sediments, and Buildings and Structures

BASIC DOSE LIMITS

The limit for routine exposure from decommissioned facilities is 25 mrem/yr. The maximum limit for the annual radiation dose (excluding radon) received by an individual member of the general public is 100 mrem/yr. In implementing this limit, as low as reasonably achievable (ALARA) principles are applied to set site-specific guidelines. (10 CFR 20, Subpart E)

SOIL GUIDELINES

Radionuclide	**Soil concentration (pCi/g) Above Background**[a,b,c]
Ra-226 or Th-230 Ra-228 or Th-232	5 pCi/g above background when averaged over the first 15 cm of soil below the surface; 15 pCi/g above background when averaged over any 15-cm-thick soil layer below the surface layer. (40 CFR 192 and DOE Order 5400.5)
Uranium	Guideline is developed on a site-specific basis. A value of 50 pCi/g above background for U-238 and 100 pCi/g above background for total uranium applies to the St. Louis site (Fiore 1990). This value was derived in accordance with DOE Order 5400.5.

STRUCTURE GUIDELINES

Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that has no radiological restrictions on its use; structures that will be demolished or buried are excluded. The applicable generic guideline (40 CFR 192) is: In any occupied or habitable building, the objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) that shall not exceed 0.02 WL[d]. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. (40 CFR 192)

External Gamma Radiation

The average level of gamma radiation inside a building or habitable structure on a site that has no radiological restrictions on its use shall not exceed the background level by more than 20 µR/h and will comply with the basic dose limits when an appropriate-use scenario is considered. (40 CFR 192)

Indoor/Outdoor Structure Surface Contamination (NRC Regulatory Guide 1.86)

	Allowable Surface Residual Contamination (dpm[e]/100 cm^2)		
Radionuclide[f]	**Average**[g,h]	**Maximum**[h,i]	**Removable**[h,j]
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000 α	15,000 α	1,000 α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.	5,000 β - γ	15,000 β - γ	1,000 β - γ

[a] If mixtures of radionuclides occur, the concentrations of individual radionuclides shall be reduced so that (1) the dose for the mixture will not exceed the basic dose limit, or (2) the sum of ratios of the soil concentration of each radionuclide to the allowable limit for that radionuclide will not exceed 1 ("unity").

[b] These guidelines represent allowable residual concentrations above background averaged across any 15-cm-thick layer to any depth and over any contiguous 100-m^2 surface area.

[c] Every reasonable effort shall be made to remove any source of radionuclide that exceeds 30 times the appropriate limit for soil, irrespective of the average concentration in the soil.

[d] A working level (WL) is any combination of short-lived radon decay products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

[e] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[f] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

[g] Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

[h] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at a depth of 1 cm.

[i] The maximum contamination level applies to an area of not more than 100 cm^2.

[j] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent pater, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that total residual surface contamination levels are within the limits for removable contamination.

The UMTRCA standards for inactive uranium processing sites are organized into control standards (Subpart A), standards for cleanup (Subpart B), and implementation including supplemental standards (Subpart C). Control standards provide for the long-term stabilization and isolation of residual radioactive material (ie, tailings and process ore waste) to prevent their misuse and spread. Standards set forth in Subpart B apply to the cleanup of residual radioactive materials from land and buildings. Subpart C sets forth supplemental standards that may be applied under special circumstances that allow the selection and performance of remedial actions that come as close as reasonably achievable to meeting the more stringent standards of Subparts A and B. Subparts D and E provide standards for managing uranium and thorium by-product materials at licensed commercial uranium sites. Subparts A, B, and C and certain parts of Subparts D and E of 40 CFR 192 are relevant and appropriate to SLDS.

40 CFR 192.02 Subpart A, which addresses releases of radon from tailings piles, is considered relevant and appropriate to those aspects of the remedial alternative which involve waste disposal. Only selective subsections of Subparts D and E are relevant and appropriate because the waste management activity (ie, disposal as opposed to by-product operational processing) and the associated potential release issues could be considered sufficiently similar:

- Subpart A specifies standards for the control of residual radioactive materials from inactive uranium processing sites designated under Section 108 of UMTRCA. Since SLDS is not a designated uranium mill tailings site under UMTRCA, these requirements are not directly applicable; however, some of the requirements would be relevant and appropriate. 40 CFR 192.02, which addresses releases of radon from tailings piles, is considered relevant and appropriate to those aspects of the remedial alternative which involve waste disposal. The disposal facility must be effective for up to one thousand years, to the extent reasonably achievable, and in any case, for at least 200 years. At completion, the disposal facility must provide reasonable assurance that radon-222 from residual radioactive material will not exceed an average release rate of 20 pCi/m^2-s, or increase the annual average concentration of radon-222 in air at or above any location outside the site perimeter by more than 0.5 pCi/l.

- Similarly, individual requirements of Subpart B would be relevant and appropriate to the remedial action alternative. These include requirements in 40 CFR 192.12 regarding radium-226 concentration in 100 square meters by 15 cm deep (not to exceed 5 pCi/g in top 15 cm and 15 pCi/g in lower 15 cm layers) for soil and permissible concentrations of radon decay product [not to exceed 0.02 working level (WL) where possible, and 0.03 WL in any case, both including background] and gamma radiation exposure (not to exceed 20 μR/hour above background) in habitable buildings. DOE Order 5400.5 has identical provisions, and additionally includes thorium and any other isotopes present at significant concentration. Because more than one isotope is addressed by DOE 5400.5, an additional provision is included to account for the combined effect of multiple isotopes. The sum of the ratios (SOR) of the isotopic concentrations to their guideline values should not exceed 1. The guideline values for other radionuclides are derived from dose considerations.

- Supplemental standards of Subpart C, as defined in 40 CFR 192.21-22, are considered relevant and appropriate for application to difficult-to-access soils left in place under the remedial action alternative because these soils pose no significant current risk and future exposures would be controlled by institutional controls.

- Subpart D specifies standards for the management of uranium by-product materials and Subpart E specifies identical requirements for the management of thorium by-product materials. These two subparts deal with not only management of by-product materials during processing operations, prior to the end of closure, and following processing, but also to restoration of disposal sites following any use of such sites under Section 83(b)(1)(B) of the Atomic Energy Act. Section 83(b)(1)(B) of the Act deals with the use of disposal site land. The "during processing and prior to the end of closure" [40 CFR 192.32(a)] and "following processing" [portions of 40 CFR 192.41(d)] are neither applicable nor relevant and appropriate to the SLDS remedial action. Since the radioactive materials at SLDS are the same on the isotopic level as by-product material, the specific standards 40 CFR 192.32(b) and 40 CFR 192.41(a), (b), and (c) are considered relevant and appropriate to the remedial action. The standards presented in DOE Order 5400.5 for isotopes other than radium are considered TBC guidance.

Less stringent supplemental standards may be authorized under circumstances when standard guidelines are not appropriate for a specific property or any portion of that property. Supplemental standards are discussed later in Section 3.2.1.4.

Another source of potential cleanup standards for the FUSRAP program at St. Louis are standards promulgated by the Nuclear Regulatory Commission (NRC). NRC has promulgated standards for decommissioning properties of NRC licensees and terminating NRC licenses at 10 CFR 20, Subpart E, effective August 20, 1997. These standards are applicable only to persons who hold NRC licenses, so they would not be applicable to FUSRAP activities at St. Louis. NRC regulates source, special nuclear, and byproduct materials, so these standards apply to those substances. The standards do not apply to Naturally Occurring Radioactive Materials (NORM) or natural and accelerated produced radioactive materials, nor do they apply to low-level radioactive waste as defined in the Low-Level Radioactive Waste Policy Act of 1980. However, an analysis of factors determining relevance and appropriateness yields the conclusion that the standards would be relevant and appropriate as potential cleanup standards at SLDS.

In these standards, NRC has established criteria for release of property for unrestricted use, as well as criteria for release of property for restricted use and criteria for alternate license termination. In the preamble, NRC stated a preference for release of property for unrestricted use, but acknowledged that restricted use would be allowed in cases where achieving unrestricted use would be unreasonable.

In establishing the standards, NRC continues to adhere to the 100 mrem/yr dose limit for protection of the public set forth in the 10 CFR 20 Radiation Protection Standards. With this limit as a maximum dose, NRC established criteria which would allow release of property for unrestricted use as a level of contamination allowing a total effective dose equivalent (TEDE) of 25 mrem/yr, with procedures in place to reduce the dose level ALARA. NRC did not establish a separate limit for groundwater, but has included exposure to groundwater contamination within the 25 mrem/yr dose limit.

For certain facilities, achieving unrestricted use may not be appropriate because there may be net public or environmental harm in achieving unrestricted use, that is, damage from removal, transport and disposal of materials could be larger than the benefit in dose reduction, or because expected future use of the site would likely preclude unrestricted use, or because the cost of site cleanup and waste disposal to achieve unrestricted use is excessive compared to achieving the same dose criterion by restricting use of the site and eliminating exposure pathways. Criteria for decommissioning a site by restricting use of that site must comply with the 25 mrem/yr dose limit, although that level can be exceeded in site-specific situations and under specific provisions. As with unrestricted use, procedures must be put in place that would reduce the dose level to ALARA.

Use of restrictions that employ institutional controls is appropriate in specific situations. The important question with institutional controls is whether they are sufficiently durable. Institutional controls should be established with the objective of lasting 1000 years to be consistent with the time-frame used for calculations. Then, the licensee would be expected to demonstrate that the institutional controls could reasonably be expected to be effective into the forseeable future. Further, remediation must be conducted so that the cap of 100 mrem/yr on the TEDE from residual radioactivity is met if the institutional controls were no longer effective, and that exposures be ALARA beneath the cap of 100 mrem/yr. If the 100 mrem/yr controls cannot be met, a licensee can petition for a cap of 500 mrem/yr, if he can justify it and if he meets additional requirements, such as cleaning up the site to less than that value based on an ALARA evaluation of the site; instituting durable institutional controls; and making provisions to verify the effectiveness of institutional controls at the site every 5 years after license termination to ensure that the institutional controls are in place and the restrictions are working. In addition, before decommissioning for restricted use, licensees must provide for public participation, create an opportunity for comprehensive discussion of the issues, and make available a public summary of discussion results.

A licensee may seek to terminate his license under alternate conditions other than those for restricted or unrestricted use. Sites that have large volumes of low-level contaminated waste may fall within this category. To obtain a license termination under alternate conditions, a licensee must: (1) provide assurance, using a complete and comprehensive analysis, that the dose to a critical group will not exceed 100 mrem/yr; (2) using the provisions for restricted use, minimize exposure to the site; (3) perform a comprehensive analysis of risks and benefits of viable alternatives, to reduce the residual radioactivity at the site to ALARA; (4) follow the same public participation requirements as for restricted use; and (5) obtain the specific approval of the NRC for the use of alternate criteria. Comments on the decommissioning and license termination plan from USEPA or the public must be considered by NRC in making its decision.

At SLDS, the NRC decommissioning standard is being considered as a target removal level for radionuclides below a depth of 2 ft. It is anticipated that if the NRC dose criteria of 25 mrem/yr is used as the starting point for deriving initial removal target concentrations for each depth-based exposure scenario, and for each exposure unit, and soils containing material at or above the removal target concentrations are removed, then the average site exposure point concentrations remaining will meet USEPA's dose limit and risk limit guidelines, explained below.. Meeting the cleanup level established using the 25 mrem/yr dose limit as a target removal concentration with application of ALARA principles will result in a cleanup that will allow release of the property for either unrestricted or restricted use, in accordance with USEPA's guidance for cleanup of CERCLA sites.

Criteria evaluated in an ALARA assessment include potential risks associated with exposures under current and likely future land use, as well as potential groundwater impacts associated with residual soil contamination. For contaminants remaining below the initial two feet, ALARA must consider potential groundwater impacts, exposures resulting from excavation, and maximum exposures that may be expected upon loss of institutional controls. In addition, ALARA must establish and document compliance with residual dose criteria that are developed based on restrictions associated with the intended land use.

At SLDS, it is planned that once radioactive-contaminated soils containing materials above the removal target concentrations are removed, the remaining site data will be used to recalculate average site exposure point concentrations. Remaining site data to be used are the new site or exposure unit average and the reasonable maximum exposure (RME) concentrations. These post-remedial action (RA) estimates should provide more realistic estimates of actual site conditions after cleanup, and they will also likely show that expected conditions after cleanup are more protective than the target dose limit. That is, it is expected that using the NRC's ALARA approach, with a range of potential target dose limits less than 25 mrem/yr, should result in cleanups that result in conditions that meet USEPA's 3×10^{-4} guidelines when risk is calculated on the basis of the specific isotopes present at the site.

The next step in cleanup calculations will be to use the post-remedial action (RA) modeled values for average and RME concentrations to determine risks for each exposure unit under industrial use conditions using standard USEPA CERCLA risk assessment guidance (RAGS). Field monitoring and construction oversight will be employed to assure that the residual concentrations meet the risk and dose requirements of CERCLA and the NRC. Also, use of cover may be considered, and possible passive restrictions such as deed notices, to provide assurance that the external gamma exposures above background levels from residual contamination are not significant for current workers.

Groundwater

As stated in 40 CFR 192.20, judgments on the possible need for remedial or protective actions for groundwater aquifers should be guided by relevant considerations described in EPA's hazardous waste management system and by relevant State and Federal Water Quality Criteria (FWQC), for anticipated or existing uses of water over the term of the stabilization. The decision on whether to institute remedial action, what specific action to take, and to what levels an aquifer should be protected or restored should be made on a case-by-case basis taking into account such factors as technical feasibility of improving the aquifer in its hydrogeologic setting, the cost of applicable restorative or protective programs, the present and future value of the aquifer as a water source, the availability of alternative water supplies, and the degree to which human exposure is likely to occur.

The Safe Drinking Water Act (SDWA, amended 1986) requires EPA to promulgate regulations to protect human health from contaminants in drinking water by establishing national drinking water standards and a joint federal-state system for assurance with those standards (EPA 1988b). SDWA Maximum Contaminant Levels (MCLs) are enforceable standards that apply to specified contaminants and generally are ARARs for current or potential drinking water sources within the area of attainment. MCLs are developed using cost and technical considerations and are protective of human health.

MCLs (under RCRA and under SDWA) are relevant and appropriate to remediation of groundwater that may be used for drinking. However, MCLs are generally not appropriate where groundwater is not potentially drinkable due to poor water quality; or due to location in a large industrial area where soil and groundwater degradation has occurred and where a high potential for continued degradation exists; or where there is no actual, planned or potential use of groundwater for drinking; as is the case for SLDS. In addition, MCLs are generally not appropriate for site-specific circumstances where it is unlikely that a well would be placed and groundwater would thus not be consumed (eg, a narrow strip of land between the toe of a landfill and a river, if there are surface water impacts resulting from anthropogenic sources of PCOCs at the site (EPA 1988b).

To determine if any requirements of the SDWA are ARARs at SLDS, an evaluation of whether site surface waters or site groundwater, which are current or potential sources of drinking water, receive or could receive contamination from the site sufficient to pose a risk to human health or the environment must be made. For surface water, the sheer discharge of the Mississippi River coupled with any viable radioactive migration to the river, even under current site conditions, results in such extensive dilution that there is not a significant risk to human health or the environment. If contaminants in groundwater reach the Mississippi River, they are below drinking water MCLs.

More recent EPA groundwater protection guidance states that the goal for groundwater, which is hydrologically connected to surface water, should be to reduce contamination so that its discharge to surface water does not exceed surface water quality standards established under CWA (EPA 1992). Due to the very low groundwater flow rate relative to the surface water flow rate of the Mississippi River, contaminants carried to the river in groundwater are at levels below the water quality standards for surface water.

EPA groundwater protection guidance also emphasizes that because funding resources are limited, states must focus their groundwater efforts. Consequently, aquifers should not simply be discussed as having the potential for use in the future, but rather as having an expected use in the future. With this approach, aquifers that have the greatest value or benefit can be afforded greater attention (EPA 1992). With the Missouri and Mississippi Rivers, and other nearby surface water sources, the expected future use of groundwater near the site is minimal. This is further reinforced by the poor water quality characteristics in the bedrock and alluvium (high turbidity and high total dissolved solids) in the bedrock units.

Structures

Promulgated standards for radon in occupied or habitable buildings and in ambient air at the perimeter of storage or disposal facilities are given in 40 CFR 192. 40 CFR 192.12(b)(1) requires that radon decay product concentrations in occupied or habitable buildings should not exceed an annual average of 0.02 WL (3 pCi/L). Radon levels in ambient air are limited to an average annual concentration of no greater than 0.03 WL (5 pCi/L) (Table 3-1).

40 CFR 192.12 stipulates for external gamma radiation that "Remedial actions shall be conducted so as to provide reasonable assurance that the level of gamma radiation shall not exceed the background level by more than 20 μR/h." The indoor/outdoor structure surface residual levels in Table 3-1 for Ra-226, Th-230, Th-232, U-238, and U-natural are key radionuclide values for SLDS. These standards will be used as target cleanup guidelines for control of external gamma radiation from contaminated surfaces.

3.2.1.2 Supplemental Standards

Per 40 CFR 192, the standard for acceptable residual Ra-226 radioactivity in soil is 5 pCi/g above background, averaged over the first 15 cm of soil below the surface, and 15 pCi/g above background averaged over 15 cm-thick layers of soil greater than 15 cm below the surface (40 CFR §192.12). Federal agencies are given some leeway in meeting that standard and may substitute "supplemental standards" as long as they meet at least one of the following circumstances:

- where the remedial action required to meet the 5/15 standard would pose a clear and present risk of injury to workers or members of the public;
- where the remedial action would cause environmental harm that is clearly excessive compared to the health benefits to persons living on or near the site, now or in the future;
- where the estimated cost of the remedial action is unreasonably high relative to the long-term benefits, and the residual radioactive materials do not pose a clear present or future hazard;
- where the cost of a remedial action for the cleanup of a building is clearly unreasonably high relative to the benefits (factors to be examined include the anticipated period of occupancy, the incremental radiation level, the residual useful lifetime of the building, the potential for future construction on the site, and the applicability of less costly remedial actions);
- where there is no known remedial action; and
- where radionuclides other than Ra-226 and its decay products are present in sufficient quantity and concentration to constitute a significant radiation hazard from residual radioactive materials.

In addition, 40 CFR 192.21 criteria allow imposing supplemental standards as ARARs for establishing alternative limits to those specified in 40 CFR 192.12.

Supplemental standards may be considered ARARs for remediation of portions of the SLDS on the basis of the first three bullets above. For example, inaccessible soils at the SLDS do not pose a current risk to the general public or current employees who work in the buildings, based on the BRA analysis. Excavating the soils beneath these buildings while the buildings are still in place would increase the potential for exposure from inhalation of particulates, could undermine the structural integrity of the buildings, and would result in displacing workers at the Mallinckrodt Inc. plant, all without achieving a significant reduction in risk. There also would be increased exposure to risk associated with general construction/excavation/demolition activities. Excavation of inaccessible soils under roads and railroads would cause increases in transportation risks to the public, increased worker risk of injury and fatality, economic impact to commercial properties and railroad companies, rerouting of roadway and railroad traffic, and increases in length of time to complete remediation, again without achieving significant reduction in risk. For these reasons, supplemental standards would be appropriate.

If a federal agency elects to employ supplemental standards, the agency shall inform all private owners and occupants of the affected location and solicit their comments.

The standard of selection for a supplemental standard is one which comes as close to meeting the otherwise applicable standard as is reasonable under the circumstances. This type of determination has to be made on a site-by-site basis.

3.2.1.3 Compliance Conclusions

At SLDS, the 5 pCi/g in the top 15 cm (6 in) and 15 pCi/g below 15 cm is considered the primary cleanup standard in the top 2 ft (40 CFR 192). In addition, DOE Order 5400.5 limits on Th-230 and derived limits on U-238 will be used as TBC guidance in the absence of concentration specific ARARs for uranium and thorium. The Sum of Ratios (SOR) above background rule will be used to ensure that remedial action will be adequate to protect human health. The sum of ratios rule states that material should be removed if the sum of the ratios of the concentration above background of each isotope to its guideline limit is greater than 1. This can be expressed mathematically as

$$\frac{\text{max of Ra-226 or Th-230}}{5} + \frac{\text{max of Ra-228 or Th-232}}{5} + \frac{\text{U-238}}{50} \geq 1$$

in the top 15 cm. For each 15 cm layer below the top 15 cm interval, 15 pCi/g is used in place of 5 pCi/g in the equation above for radium and thorium. Subsequently, these criteria will be referred to as "composite criteria" because they combine elements of the relevant and appropriate requirements of 40 CFR 192 and TBC guidance of DOE Order 5400.5.

Beneath 2 ft, supplemental limits can be applied because soils at depth do not pose a current risk to the general public or employees, thus the cost is unreasonably high relative to the long-term benefits. To set limits below 2 ft, the NRC decommissioning standard (10 CFR 20) is being considered to derive target removal levels. Initial target removal levels have been derived based on evaluation of a range of possible cleanup guidelines and selection of the cleanup guideline that provides the optimum balance of protectiveness and cost. This derivation followed NRC guidances for ALARA analyses. The results of the ALARA analysis for SLDS show that use of target removal levels for the primary radionuclides of 50 pCi/g Ra-226, 100 pCi/g Th-230, and 150 pCi/g U-238 should result in a remediation that is protective under current and likely future land uses. The dose and risk associated with the selected ALARA target removal levels comply with NRC regulations on radiological cleanups (10 CFR 20).

Material requiring off-site disposal would be placed in an approved disposal facility. These criteria will be referred to in this document as ALARA criteria. The SOR rule would also be applied to the ALARA criteria using the ALARA limits as

$$\frac{\text{Ra-226}}{50} + \frac{\text{Th-230}}{100} + \frac{\text{U-238}}{150} \geq 1$$

Supplemental standards would be invoked for inaccessible soils located under buildings or railroad beds because the inaccessible soils at SLDS do not pose a risk to the general public or employees and removal of the soils would result in disruptions in the operations of both Mallinckrodt Inc. and the railroads with no significant reduction in risk.

3.2.2 Development of Media-Specific Remedial Action Objectives for SLDS

Media-specific remedial action objectives were developed for SLDS for soils, buildings and structures, and groundwater. In general, mitigation of the exposure pathways of concern and compliance with ARARs provide a framework for media-specific remedial action objectives. Media-based remedial action objectives are discussed below. Potential environmental pathways warranting mitigative measures are:

- Direct contact with soils through ingestion and dermal contact.

- External gamma radiation from the surface soil. Risks are minimal for subsurface soil containing radionuclides (more than 15 cm from surface).

- Inhalation of fugitive dust and radon gas emissions from soils.

- Ingestion of groundwater. The risk from this exposure is relatively remote because groundwater is not currently used as a potential drinking water source, groundwater is of poor quality, yields in the bedrock are poor, and the area has abundant surface water which makes future groundwater use unlikely.

- Uptake by biota (ie, animals and plants) of contamination from soil or groundwater. The risk from this exposure pathway is only a future risk (eg, produce grown in a home garden).

3.2.2.1 Remedial Action Objectives for Soils

Soils at SLDS were characterized by the BRA as posing potentially unacceptable risks to human health and the environment due to the following MED-related PCOCs: Ra-226, Th-230, Th-232, U-235, U-238, and their respective radioactive decay products. Remedial alternatives developed to address contamination in soils should consider elimination or mitigation of the exposure pathways listed above and compliance with guidelines (Table 3-3).

Table 3-3. Remedial Action Objectives for Remediation of SLDS

Medium	Remedial Action Objective
Soils	• Prevent exposures from surface residual contamination in soils greater than limits prescribed by 40 CFR 192 • Eliminate or minimize the potential for humans or biota to contact, ingest, or inhale soil containing COCs • Eliminate or minimize volume, toxicity, and mobility of impacted soil • Eliminate or minimize the potential for migration of radioactive materials off-site • Comply with ARARs • Eliminate or minimize potential exposure to external gamma radiation
Building and Structure Surfaces	• Prevent or reduce exposures from surface residual radioactivity in buildings and structures greater than the limits prescribed by 10 CFR 20 Subpart E • Eliminate or minimize toxicity, or mobility, and/or volume of COCs • Comply with ARARs • Eliminate or minimize potential exposure to external gamma radiation
Groundwater	• Eliminate or minimize exposure to COCs in the future • Eliminate or minimize potential leaching and migration of COCs in groundwater off-site

3.2.2.2 Remedial Action Objectives for Radioactively Contaminated Buildings

The remedial action objectives developed for the radioactively contaminated buildings at SLDS involve elimination or minimization of the potential for direct contact with radioactivity and prevention or reduction of further migration via building surfaces or ambient air. 10 CFR 20 Subpart E establishes the cleanup requirements for buildings and structures (Table 3-3).

3.2.2.3 Remedial Action Objectives for Groundwater

Remedial action objectives for groundwater are to eliminate or minimize potential human contact with contaminated groundwater and to reduce potential for radionuclides to leach into groundwater (Table 3-3).

3.3 GENERAL RESPONSE ACTIONS

GRAs that could be implemented to achieve the remedial action objectives and goals described in Section 3.2 reflect the current understanding of contaminants and environmental conditions at SLDS. These GRAs include no action, institutional controls, containment, removal, treatment, and disposal.

3.3.1 No Action

The no-action response means that no new action would be taken. Whatever is in place at the present time, such as perimeter fencing with signs and existing environmental monitoring, would continue under the no-action response. The no-action alternative is required by the NCP to provide a baseline for evaluating other GRAs, options, and alternatives. Effectiveness for future conditions is projected on the basis of current conditions. Although interim remediation activities may have previously been implemented at the site, no further action would be taken. Current maintenance and monitoring activities, however, would continue.

3.3.2 Institutional Controls

The primary goal of institutional controls is to prevent access to contaminated areas. Where active response measures, such as treatment, containment or beneficial use of source material, are determined not to be practicable, the NCP allows the use of institutional controls to supplement engineering controls for short and long-term management of hazardous substances, pollutants, or contaminants [(40 CFR, 300.430(a)(1)(*iii*)(D)]. Some of the controls possible include land-use restrictions, resource restrictions, deed restrictions, well-drilling prohibitions, building permits, well-use advisories, and deed notices. Institutional controls, either alone or in combination with engineering controls, might be appropriate to achieve the protection of human health and the environment.

3.3.3 Containment

Containment technologies can effectively reduce PCOC mobility and potential for exposure, but they do not reduce contaminant volume or toxicity. In situ containment technologies for SLDS include capping for soils, surface sealing and radon controls for buildings, and grout injection and slurry walls for groundwater.

Capping involves covering an area with a low-permeability material to reduce the migration of contaminants by free release to the atmosphere or to adjacent soils and groundwater. Capping reduces the infiltration of surface water through contaminated media to the groundwater, but does not reduce the toxicity of source materials. Capping also can minimize the release of dust and vapors into the atmosphere, thereby minimizing any potential for inhalation or redeposition onto another area and reduce direct radiation exposure.

Containment technologies for groundwater prevent the natural movement of the groundwater. Groundwater containment is achieved by controlling groundwater migration from the site through the installation of vertical and/or horizontal barriers. Vertical barrier walls in the form of slurry walls, grout curtains, vibrating beams, or steel sheet piling would have to be constructed down to a natural horizontal barrier that significantly retards vertical contaminant migration in the groundwater such as a clay zone or bedrock to be effective in impeding groundwater flow. Horizontal barriers such as slurry walls were considered in controlling groundwater migration. Capping is often performed in conjunction with groundwater containment to minimize the volume of infiltrating water and to serve as a means of source control.

The containment technologiesrelated to buildings/structures involve sealing the surface with sealants to prevent direct contact with the contaminants and to reduce contaminant mobility. Technologies for surface sealing include painting (applying paints on masonry and wooden surfaces), applying resins or liquid plastic (spraying on resins or plastic material to form a barrier or applying foam), and application of other impermeable materials (using plastic sheeting or wooden structures to provide a barrier).

3.3.4 Removal

Removal of contaminated material, also referred to as source removal, effectively limits the volume and mobility for PCOCs at the source area and can facilitate treatment and disposal. Removal measures will be considered for all contaminated media at SLDS. The appropriate removal technology and process option is a function of their physical properties.

Excavation with conventional earth-moving equipment is used to remove bulk material such as soil. Manual excavation may be required around utilities and in areas where access is limited.

Demolition is used to raze an entire building if the building is contaminated or if access to underlying contaminated soils is required. Partial dismantlement and restoration is the selective elimination of contaminated portions of buildings, structures, or equipment by various means of dismantlement. Partial dismantlement and restoration is used when only portions of a building or structure or associated equipment are contaminated and cannot be decontaminated in a cost-effective manner.

Technologiesthat extract contaminated groundwater include passive interceptor systems and pumping well systems. Passive interceptor systems consist of trenches or drains excavated to a depth below the water table and a collection pipe placed in the bottom of the trench. Pumping well systems are used for hydrodynamic control of contaminated groundwater by manipulating the hydraulic gradient of groundwater through injection or extraction of water. Well systems may require the installation of several wells at selected sites.

3.3.5 Treatment

Treatment encompasses a wide range of physical, chemical, and biological technologies to address the PCOCs in different media. Treatment can permanently and significantly reduce contaminant volume, toxicity, and/or mobility.

Physical treatment includes solids separation, size reduction, soil washing, and immobilization. Solids separation uses physical separation techniques to segregate waste materials by size, type, or levels of contamination. Size reduction involves grinding, shredding, or dismantling large pieces of waste materials into smaller pieces. Soil washing involves the application of water or other solvents to the waste material in order to isolate the contaminants by separating them by particle size. Immobilization involves the addition of chemicals to waste materials that solidify the contaminated material.

Dewatering technologies such as evaporation, vacuum filtering, gravity thickening, etc. are not effective in treating contaminants but may be used as secondary treatment processes to reduce contaminant volumes and improve handling characteristics. These processes are not considered stand-alone options.

Chemical processes include chemical stabilization and fixation techniques to form an organic polymer with the waste materials. The stabilization and fixation technologies are used to bind the contaminants and thereby reduce potential mobility. Acid extraction is another chemical processing technology considered. Acid extraction leaches contaminants from the waste matrix. Typically, the extract solution is neutralized and the contaminants removed by wastewater treatment techniques such as ion exchange or precipitation.

Biological techniques are generally used to biodegrade organic contaminants and are generally not effective on metal or radioactive contaminants. Phytoremediation is used to concentrate metals and radionuclides through uptake by plant roots. Plant roots do not penetrate deeply enough to address the deep contamination at Mallinckrodt Inc. Biological treatment technologies will not be retained for further consideration.

Incineration technologies combust waste materials with a rotary kiln or fluidized bed process or by in situ vitrification. Conventional incineration technologies are used extensively for destroying organic compounds, but are not effective for inorganic contaminants of the type at the SLDS. Incineration would not significantly reduce waste volume for St. Louis soils and would generate waste streams requiring additional treatment or disposal.

In situ vitrification involves placing electrodes into contaminated soil and applying electric current to melt the soil which then solidifies into a glassy matrix resembling obsidian. Vitrification can also be accomplished ex situ at a vitrification facility.

Decontamination of buildings and structures could include physical and chemical treatment technologies which significantly reduce volume compared with dismantlement or demolition. Physical decontamination technologies use force to mechanically remove contaminants from material surfaces. Physical decontamination technologies include scrubbing, scraping, vacuuming, wiping, scabbling, high pressure water, CO_2, or crystallized ice. Chemical decontamination technologies use water, solvents, complexing agents, acids, and bases to dissolve or suspend contaminants in the decontamination fluid to facilitate removal from the material surface.

Groundwater (including water from soil dewatering during excavation) remediation technologies considered as treatment include air stripping, carbon adsorption, ion exchange, reverse osmosis, and evaporative recovery. All these technologies require pumping the groundwater out of the soil for treatment. Some of the treatments listed here are not effective for radionuclides, but may be required to remove organic contaminants prior to discharge.

3.3.6 Disposal

Disposal involves the permanent and final placement of waste materials in a manner that is protective of human health and the environment. Untreated waste, contaminated soil, or concentrated waste can be disposed off-site in an approved and licensed disposal facility or may be recycled for beneficial reuse (eg, fill material for airports, road beds, landfill cover material). Concentrated waste from treatment processes can be disposed of either off-site in an approved facility or onsite in a permanent disposal cell.

Interim storage would reduce the mobility of the waste materials by temporarily isolating the contaminants and eliminating potential exposure routes. Interim storage would involve an existing or new structure to contain excavated waste materials. This option is considered only as an interim action prior to final disposal.

Discharge options for treated water include discharge to surface water or to a POTW in accordance with permitting. Evaporation (natural or forced) could also be used.

A key element of activities resulting in waste generation is the minimization of waste volumes. Waste minimization is an important consideration for any activity that results in waste generation. It could involve recycling of work items (eg, tools, hardware, protective equipment) and beneficial reuse of materials (eg, soil). For example, use of soil as fill at an appropriate site or incineration of disposable items such as wood, paper, plastic, and personnel protective equipment are waste minimization measures. Surface decontamination of buildings and structures is another waste minimization measure. The application of waste minimization principles and technologies will be pursued during site remediation.

3.4 SUMMARY OF REMEDIAL ACTION TECHNOLOGIES AND PROCESSES

This section summarizes the ISA for the St. Louis site (SAIC 1992) and discusses technology/process specifics of excavation, containment, treatment, decontamination/dismantlement, dredging, and institutional controls.

3.4.1 Summary of Initial Screening of Alternatives (ISA) Document

Remedial action technologies that could be used to implement GRAs were identified and evaluated in detail in the ISA report for the St. Louis site (SAIC 1992). The St. Louis ISA, which is one of the St. Louis site RI/FS process core documents, was prepared prior to the FS for the purpose of performing an initial screening of the available technologies for each of the contaminated media. In that document the universe of available technologies was narrowed to only those applicable to St. Louis site media contaminant types and concentrations and site-specific conditions. The ISA Chapter 2 presents all remedial options considered along with a short description of the process option and the evaluation of the available technologies against effectiveness, implementability, and cost, as defined below:

- effectiveness in terms of overall protectiveness of human health and the environment in both the short term and the long term and in reducing contaminant toxicity, mobility and/or volume;

- implementability in terms of technical feasibility, administrative feasibility, and resource availability; and,

- cost in a comparative manner (eg, low, moderate, or high) for technologies of similar effectiveness or implementability.

The ISA document identifies potentially viable technologies and processes retained for consideration at the St. Louis site as components of the remedial alternatives. Retained technologies are subsequently combined to form a broad range of alternatives for each remedial unit. The ISA Chapter 3 identifies the alternatives that are carried forward to the FS development and screening of remedial unit alternatives for further evaluation. Table 3-4 summarizes the remedial action processes relevant to SLDS that were carried forward to the FS remedial alternatives screening process.

Table 3-4. Summary of Selected Remedial Action Technologies for SLDS

General Response Action	Soils	Buildings and Structures	Groundwater
No Action	Periodic monitoring of contaminant concentrations and locations	Monitoring of contaminant concentrations and locations	Monitoring
Institutional Controls	Access restrictions; land use restrictions; monitoring	Access restrictions; land use restrictions; monitoring	Groundwater restrictions; monitoring
Containment	Clay cap; multimedia cap; soil cover	Surface sealing; radon controls	Slurry walls; grout injection
Removal	Excavation	Partial demolition; complete demolition	Extraction wells; extraction/injection wells
Treatment	Immobilization; vitrification; soil washing; screening; gravity/paramagnetic separation; solvent extraction	Chemical/physical decontamination	Source removal; extraction wells; air stripping; carbon adsorption; ion exchange; evaporative recovery
Disposal	Onsite; off-site (see Section 5)	Onsite; off-site (see Section 5)	Discharge to surface water; publicly-owned treatment works

3.4.2 Excavation/Source Removal

Contaminated soil at the site can be partially or completely excavated with conventional earth-moving equipment including backhoes, bulldozers, front-end loaders, and manual techniques. Equipment to be used is determined by many factors, including the area to be remediated, the area available for operations, the depth of the excavation, and the capabilities of the equipment. Manual excavation techniques are used where insufficient space precludes the use of conventional equipment. Conventional construction techniques would be employed to minimize impacts to groundwater and surface water during excavation.

Contaminated surface soils that cover smaller areas may be excavated using digging equipment such as backhoes. Bulldozers or front-end loaders can remove relatively shallow, wide areas of contaminated soil. Bulldozers are versatile machines used on projects such as moving earth for short haul distances, spreading earth fill, backfilling trenches and pits, clearing sites of debris, and pushing debris into loading areas. Front-end loaders, also called tractor shovels, are used extensively in construction to load bulk material such as soil, rocks, and rubble into dump trucks, to move earth forward for short distances, and to excavate. Self-loading scrapers could be used for wide, shallow contaminated soil areas.

Generally effective to a depth of 1 to 2 ft, front-end loaders can scoop surface soils either into a temporary pile that can then be loaded in dump trucks, or directly into the transport container. Loaders are generally most effective on coarse, noncohesive soils. The depth of excavation must be taken into account, because there is a physical limitation on the reach of hydraulic arms. If soil removal must extend beyond 1 or 2 ft depths, hoes are more generally applicable, due to their greater depth-handling capacity. Contaminated soil in space restricted locations, such as next to buildings or culverts, can sometimes be accessed with backhoes using smaller buckets or with smaller earth removal equipment.

Dump trucks serve only to haul soil, rock, aggregate, and other material. Because of their speed, they provide high earth-moving capacity at relatively low hauling cost. They also provide a high degree of flexibility, as the number and type of trucks in service may easily be increased or decreased to modify the total hauling capacity of a fleet.

The term "hoe" applies to any excavating machine of the power-shovel type (eg, hoe, back hoe, back shovel, or pull shovel). Hoes are most suited to excavating trenches and pits and to general grading work that requires precise control of excavation depth. They are superior to drag lines for close-range work and for loading excavated material into dump trucks. Hoes can work from an unimpacted area, contaminating only their buckets.

In some cases, it may be necessary to reroute drainage culverts to gain access to soils under them, or to use smaller equipment, possibly to the extent of using shovels to remove soil manually. Excavation and removal of contaminated sewer and drain lines would involve tracing a line through a variety of techniques (dyes, smoke, radio transmitters).

Confirmational field monitoring would be conducted during soil excavation to ensure that all contaminated soils have been removed to the specified remediation level. As required, samples may be collected from the excavation side walls and bottom for laboratory analyses to confirm the results obtained during field monitoring.

All excavation technologies are retained for further evaluation.

3.4.3 Containment

Containment actions include technologies that involve little or no treatment but protect human health and the environment by physically precluding contact with the contamination. The contaminated media is not chemically or physically changed, nor are the volumes of contaminated media reduced. Containment response actions prevent contaminant migration and eliminate routes of exposure.

Engineered cells and engineered multilayered caps with soil covers can be used to cover the contaminated soils and sediment at appropriate locations of the site to prevent direct contact with the waste, and to minimize the diffusion of radon gas. The radionuclides present on the surface of buildings and structures can be contained by applying a sealant. For groundwater containment, actions involve separating the contamination source from the water and controlling migration of groundwater from the site through the installation of vertical or horizontal barriers.

Engineered Cell

The engineered cell features considered important for the waste of concern here involve:

- bottom and side clay layers to impede movement of contaminated water into the ground; and
- multilayer cap cell cover designed to meet drainage, frost protection, erosion protection, water infiltration, biotic intrusion, and radon emission requirements.

The bottom and side clay layers provide isolation and would use naturally occurring clays. The availability and cost of the clay needs to be considered when planning the final design. The final selection and thickness would be included in the final design phase of the remedial process. The multilayer cap cell cover technology considerations are discussed below under the engineered cap subsection.

Before construction begins, the area to be used for the cell would be surveyed to lay out the exact location of the cell and to locate underground utilities. Geotechnical analyses, including permeability testing, density testing, moisture content, etc. would be required if clay or native soil were used in the cell. Geotechnical logs have shown that in situ contaminated soil would require some compaction to control subsidence. If required, excavation, screening out of deleterious materials, then spreading and compacting would be used to ensure the viability of a cell.

Engineered Caps

Specific design issues of the cap would be studied and addressed during the remedial design phase. The proposed capping system would be designed and constructed to:

- promote long-term minimization of surface water infiltration through the waste matrix,
- reduce external gamma radiation and radon emissions,
- function with minimal maintenance, and
- accommodate settling and subsidence to ensure the integrity of the cover.

Containment of contaminants in soils can be provided by native soil, clay, synthetic liner, or a multimedia cap. The availability and cost of the material required to construct the cap needs to be considered when planning the final design. The final selection of the membrane material and its thickness would be included in the final design phase of the remedial process.

Before construction begins, the area to be capped would be surveyed to lay out the exact location of the cap and to locate underground utilities. Geotechnical analyses including permeability testing, density testing, moisture content, etc., would be required if clay or native soil were used as the capping material. Geotechnical logs have shown that in situ contaminated soil would require some compaction to control subsidence. Perhaps excavation, screening out of deleterious materials, then spreading and compacting could be used to ensure the viability of a cap. Another approach to addressing subsidence would be to use a temporary cover until the in situ contaminated soil is stable and then apply the cap.

Sealing of Surfaces

Surface sealing involves covering the contaminated surface with a sealant that prevents the release of radionuclides into the environment. Several sealing methods are available. The most common method involves covering contaminated surfaces with a relatively tough material (eg, covering a contaminated floor with ceramic or vinyl tile). Other common methods involve covering surfaces such as walls and ceilings with paints, stucco, or polymers (polyethylene glycol). The major constraint of surface sealing is that the covering must be able to resist the normal physical stresses imposed by the location, such as temperature changes, pressure loading, humidity, abrasion, and chemical and biological effects.

The contaminated surfaces would be vacuumed and cleaned before the application of the surface coating. The existing and foreseeable use of the building and the nature of the surface to be sealed must be considered. After application, the sealant should be inspected to ensure that it is properly applied and has cured.

Radon Control Measures

Radon controls systems can be passive or active collection systems. Active and passive collection systems around building structures and ventilation systems inside buildings are effective in controlling radon gas from underlying soils. Sealing basement walls and floors will also prevent radon entry into buildings. This method will only be effective if the surfaces are continuous with no cracks or open spaces and can be completely coated with a nonporous sealant. Electrostatic precipitators (ESPs) are effective in controlling particulates (dust) inside buildings. Although radon is a gas, its decay products are highly charged particles which readily adhere to small dust particles. All mentioned radon control measures prevent entry of radon gas inside buildings, but do not control radon gas generation.

Groundwater and Surface Water

Potential groundwater containment technologies include horizontal and vertical hydraulic barriers. Potential surface water control technologies include grading, revegetation, and diversion controls. Based on site hydrology, hydraulic barriers for groundwater control were determined to be potentially viable at SLDS. The primary objectives of the barriers would be to prevent contact of uncontaminated groundwater with contaminated soils and to prevent migration of contaminated groundwater. Slurry walls were identified as a potentially viable vertical barrier option. Grout injection to seal groundwater from the source area especially under buildings was chosen as an option for horizontal barriers.

Slurry walls are the most common subsurface barriers because they are relatively inexpensive in relation to comparable subsurface barriers. Slurry walls are constructed in a vertical trench excavated under a slurry. The slurry acts essentially like a drilling fluid by hydraulically shoring the trench to prevent collapse, and, at the same time, forming a filter cake on the trench walls to prevent high fluid losses into the surrounding ground. Slurry walls have been demonstrated to be effective vertical barriers at several NPL sites. Pilot testing would be required to determine if the slurry wall construction materials would be compatible with contaminants present in the soils.

Grout injection involves emplacement of a bottom seal by grouting. It involves drilling through the site or specific directional drilling from the site perimeter, and injecting grout to form a curved or horizontal barrier. Grout injection could potentially be used as a horizontal barrier under buildings at SLDS.

Similar objectives are achieved by using the engineered cell and engineered cap. The cap will be retained as the representative technology for soil containment. Radon control measures and surface sealing will be retained for building containment. Slurry walls will be retained for groundwater containment.

3.4.4 Treatment

Soil remediation technologies considered for application at SLDS are enhanced solidification/ stabilization, vitrification, and soil washing. These technologies have been used to treat soil for radioactive contamination with varying degrees of success. Extensive treatability testing would be required to evaluate the effectiveness of any treatment process towards the SLDS soils prior to full-scale implementation. The following discussion describes those soil treatment technologies which hold the potential for use if they mature to the technical and cost effective stage before completion of remedial design.

Immobilization

Immobilization, encompassing both solidification and stabilization, is valuable for reducing contaminant migration for media that show high migration rates. Solidification does not necessarily involve any chemical change in the contaminants or any chemical interaction between the contaminants and the material used to encapsulate them. Stabilization is the conversion of contaminants to their least soluble, mobile, or toxic state. It may or may not involve a physical or chemical change. Immobilization systems are available as both in situ and ex situ processes. Immobilization processes can use cement, pozzolanic materials (siliceous materials mixed with lime), silicates (siliceous materials mixed with calcium and dry alumina), or thermally sensitive materials (thermoplastics). Each of these binders must be evaluated to determine the binder/waste/water (if applicable) ratios, strength of the immobilized matrix, and leachability of contaminants from the matrix. These technologies usually result in a larger volume of waste to manage.

Use of solidification/stabilization to reduce the migration/mobility of the radioactive contaminants in SLDS soil is not justified because of the naturally low radionuclide mobility properties of these clayey materials that underlie the fill (Section 2.2.3.2). Based on the Superfund Innovative Technology Evaluation program testing and analysis, the impact of solidifying soils on the leachability of metals or radionuclides can be quantified by calculating the migration potential. The migration potential is obtained from leach testing by dividing the weight of a metal in the leachate by the weight of the metal in the solid leached. An upper bound value for the migration potential of uranium, thorium, or radium is estimated to be 100. This value is based on results for heavy metals and is considered conservative because of the tendency of radionuclides to be strongly adsorbed on the St. Louis clayey soil. The solute transport rate for uranium, which is the most mobile of the three radionuclides, in the St. Louis clayey soil is a low value of 1.2×10^{-8} cm/sec and is a result of the low groundwater flow velocity of 1.2×10^{-5} cm/sec and a retardation factor of 1,014 (BNI 1994b).

Based on the EPA Handbook (EPA 1986a), it is estimated that the cost to solidify the St. Louis soil in cement is roughly $98/m^3 ($75/yd^3). For a soil volume of 138,000 m^3 (180,000 yd^3) [note: the in-situ soil volume adjusted to account for 20% over excavation and 25% expansion factor], the cost of solidification is $13.5 million. With an additional 30 percent volume increase due to the solidification in cement, the volume becomes 179,000 m^3 (230,000 yd^3). Thus, the use of solidification would increase the burial volume and the disposal costs, and reduce the migration rate from the low value of 1.2×10^{-8} cm/sec to, at best, 1.2×10^{-10} cm/sec. Based on this analysis, solidification/stabilization is not retained for further consideration.

Vitrification

Vitrification uses high temperature to heat and melt contaminated soil, dewatered sludge, and/or sediments. The heat source can be electric, plasma arc, or fossil fuel-fired. Processing requires that sufficient glass-forming materials (eg, silicon and aluminum oxides) be present within the waste materials to form and support a high-temperature melt. To form a melt, sufficient (typically 2 to 5 percent) monovalent alkali cations (eg, sodium and potassium) must be present to provide the degree of electrical conductivity needed for the process to operate efficiently. If the waste material does not meet this requirement, fluxing materials such as sodium carbonate or ash can be added to the base material. Typically, these conditions are met by most soils, sediments, tailings, and process sludges. The main process residual is a vitrified solid containing the contaminated soil. Typically, the residual product is a slag approximately ten times stronger than unreinforced concrete, both in tension and compression, with decreased contaminant mobility. It is usually not affected by either wet/dry or freeze/thaw cycling.

Vitrification would greatly reduce the mobility of radioactive contaminants in soil. Vitrification, however, requires an enormous amount of energy, and therefore cost, to melt and vitrify soil. Consequently, vitrification is more appropriately suited for applications where mobile contaminants pose a very significant risk to human health (ie, high-level radioactive waste), where contamination is highly concentrated or where the total volume of waste is relatively small. The estimated total volume of soil is 138,000 m^3 (180,000 yd^3). Based on a cost of \$300/m^3 (\$230/yd^3), vitrification would cost approximately \$41 million, making soil vitrification cost-prohibitive on such a large scale (MK-Ferguson 1992). For these reasons, soil vitrification is not retained for further consideration.

Enhanced Soil Washing

Enhanced soil washing can potentially achieve the goal of separating contaminated soil into less contaminated and more contaminated fractions for ultimate disposal. Traditional soil washing techniques can be used to mechanically or chemically scrub soils to remove contaminants. Radioactive contaminants tend to attach themselves to the silt and clay particles of the soil that tend to be much finer than the sand and gravel particles. Soil washing processes separate fine silt and clay particles in the soil from the coarse sand and gravel particles. The result is that the radioactive contaminants tend to be concentrated in the fine particle fraction.

Conventional soil washing technologies usually mix contaminated soil with water and mechanically scrub and separate the soil fractions to remove the contaminated soil fines. Soil washing technologies separate the finer fraction by progressive scrubbing, resulting in a separation of contaminated and noncontaminated (ie, below residual criteria) fractions. Larger, less contaminated soil fractions are removed from each stage of the processes. The remaining finer, more contaminated soil fraction can either be processed through an alternative treatment technology or dewatered and disposed. Soil washing process water is filtered and recycled.

Conventional soil washing technologies, which apply to soils that are less than 30 percent fine by weight, have not proven viable for the St. Louis soils in treatability tests conducted at SLAPS because that soil has 94 percent fine particles by weight, a percentage that inhibits mechanical soil washing processes. The contamination at SLDS, however, is mostly within the coarse fill material, therefore, soil washing may be a viable alternative for the downtown site.

Commercial soil washing technologies can either be built onsite or a portable system can be mobilized to the site. The site of an onsite facility would be prepared and developed according to conventional engineering and environmentally sensitive designs and practices. The effectiveness of conventional soil washing processes may be enhanced by the use of additional technologies such as chemical extraction, density separation, and paramagnetic separation.

Chemical extraction mobilizes contaminants through a single or multistep procedure, depending on the chemical reaction (ie, oxidation, reduction, or complexation). Chemical extraction technologies use chemical agents to leach contaminants from the soil and create a treatable liquid waste stream. The extraction agent is separated from the contaminant, usually in ways that enable the extraction agent to be fully reconstituted and reused. Extracting contaminants from fine soil particles such as those at SLDS may require longer leaching times than would coarser-grained soils. Treatability studies conducted on mixed waste soils indicate that sulfuric acid, hydrobromic acid, and sodium carbonate are potential extraction agents.

Density separation uses material density differences to separate contaminants from soil particles. This separation technology depends upon high specific gravity contaminated particles that exist as discrete particles or on high specific gravity solid organic materials adsorbing contaminants from the soil.

Paramagnetic separation exploits the slight differences in paramagnetic susceptibility of soil and contaminants. Conventional separators use a magnetic force aligned with flow direction to attract particles toward a magnetized collecting surface. The magnetic force at the collecting surface decreases abruptly with distance. Because the force experienced by any particle depends on its position within the magnetic field, particles passing close to a surface are captured, while particles passing farther away are not.

Enhanced soil washing could potentially reduce contaminated soil volumes thereby minimizing the cost of further treatment or disposal. Enhanced soil washing has proven effective as a mining extraction technique for the economic recovery of low metal content ores. Considering the estimated volume of contaminated soil that could be treated, the economy of scale could possibly make enhanced soil washing more cost effective. Extensive treatability testing would be required, however, to optimize the process and document the potential effectiveness of this technology on SLDS soils (McNeill 1992). Additionally, further consideration must be given to the ultimate fate of concentrated waste streams generated as a result of the soil washing, such as soil washing fluids and solid wastes. These waste streams would have to undergo further treatment before disposal. Enhanced soil washing is retained for further consideration.

Soil Sorting

Several companies have developed conveyor-based soil sorting systems in recent years to separate radioactively contaminated soil from unimpacted soil. These systems utilize a radiation detector array to characterize a thin layer of soil on the conveyor belt as it passes beneath the detectors. Spectroscopic analysis enables the system to evaluate the level of contamination in the soil and divert soil that exceeds radiologic criteria.

Soil sorting has been successfully used to reduce contaminant volume at the New Brunswick FUSRAP site. The coarse fill material that characterizes the shallow soil at SLDS may be amenable to soil sorting technology, however, treatability tests would need to be performed prior to implementation of this technology.

Groundwater Treatment

Groundwater (including water from soil dewatering during excavation) remediation technologies considered for application at the SLDS include air stripping, carbon adsorption, ion exchange, reverse osmosis, and evaporative recovery.

Air stripping uses air to remove water-borne organics and radon gas. Liquid-phase carbon adsorption is used as a polishing step to treat hard-to-remove organics and radionuclides. Ion exchange and reverse osmosis (membrane filtration) were considered for removing radionuclides and concentrating the radionuclides from the aqueous stream. Ion exchange involves the interchange (or adsorption) of ions between the aqueous solution and a solid resin. Ion exchange systems may be either fixed bed or moving bed. Reverse osmosis can be used to remove radioactive contaminants by taking advantage of the differential movement of dissolved material across a membrane. Reverse osmosis, however, is energy intensive and can be easily disrupted with fluctuations in influent conditions. Evaporative recovery uses the distillation process to produce distillate and a waste concentrated stream. It can be a pretreatment step before ion exchange.

Precipitation/flocculation/sedimentation, aeration, filtration, soil dewatering, and sludge dewatering are pretreatment technologies required to implement groundwater treatment options. Precipitation effectively removes metals and radionuclides. Aeration may be required as a pretreatment step to precipitation. Filtration effectively removes suspended solids from the precipitation process. Generated sludges will have to be dewatered before disposal. Discharge options for treated water and sludge disposal options must be evaluated prior to implementing these technologies. The substantive requirements of NPDES permitting would have to be met prior to discharge of treated effluent.

Groundwater at the site can be collected for treatment by passive interceptor systems or pumping well systems. Passive interceptor systems consist of trenches or drains excavated to a depth below the water table connected to a collection pipe. The groundwater is then collected for treatment and discharge. Pumping well systems are used for hydrodynamic control of the groundwater by manipulating the hydraulic gradient through injection or extraction of water. To be effective, well systems require the installation of several wells at selected sites.

For soil, both soil washing and soil sorting are retained as treatment technologies. For groundwater, the treatment technologies precipitation/flocculation/sedimentation are retained with ion exchange as a polishing step.

3.4.5 Decontamination/Dismantlement

Many potentially effective decontamination technologies, considered as treatment technologies, are available that can remove contaminants from building surfaces and provide volume reduction in place of dismantlement or demolition. When feasible, simple, non-destructive or non-intrusive decontamination techniques would be used first. These techniques include High Efficiency Particulate Airborne (HEPA)-filtered vacuuming, damp cloth wiping and washing/scrubbing operations. When non-destructive or non-intrusive methods fail to reduce surface contamination to target levels, more aggressive decontamination methods may be applied. Aggressive decontamination methods are required to remove existing surface coatings, such as paints and varnishes, as well as base layers of the surface material. All of the aggressive decontamination methods may generate dust and rubble which necessitate the use of contamination control devices and methods. Portable HEPA-Filtered Ventilation Units are used to control airborne particulates.

The more aggressive decontamination technologies involve using various combinations of the following elements:

- pressurized air or water;
- surface abrasion/scabbling using abrasive media such as metal shot, glass beads, carbide bits, grit, or other hard materials;
- water treatment to remove particulates or dissolved materials; and
- liquid cleaning agents.

The criteria used to evaluate the relative effectiveness and ease of implementation of decontamination technologies were:

- Effectiveness in removing contaminated concrete surfaces. This report assumes that physical removal of the top one-sixteenth of an inch of material will achieve acceptable levels of residual radioactivity in most areas. Where acids or water may have promoted additional leaching or in areas that are cracked, decontamination may have to go deeper.
- Generation, processing and disposal of waste streams.

Decontamination methods involving the use of these technologies may be performed on structures and building surfaces that have measurable residual contamination. In the few cases where chemical and water decontamination methods are used, the liquid wastes would be processed prior to disposal. The generation of liquids would be held to a minimum. After analysis, the liquid would be either treated for unrestricted release or solidified. Chemical decontamination methods that use strong chemicals to etch or dissolve part of the surface material are not appropriate for use with radioactive contaminants if their use results in generation of mixed wastes.

It is sometimes prudent to protect unimpacted work area surfaces before radiological work is initiated, or to fix otherwise transferable contamination on surfaces to be handled. A good quality fixative on porous surfaces is helpful in contamination control. Wrapping items with plastic sheeting and applying strippable coatings are potentially effective ways to protect uncontaminated surfaces.

Spray application of strippable coatings, such as ALARA 1146© and ISOLOCK 300©, can be used with subsequent physical peeling of the coating from the surface along with any loose or weakly adhering contamination. These coatings are approved for disposal at low-level radioactive waste disposal sites and do not generate a mixed waste.

Demolition would be performed on surfaces in buildings where decontamination methods prove unsuccessful or would not be cost effective. An estimated 20 to 50 percent of the surfaces that are above guidelines could require demolition.

Contaminated pipes/drains may be internally decontaminated by applying high-pressure water through hydro-driven nozzles. The nozzles are directed into the opening of each drain until it is cleared. The water utilized in the decontamination operation would require treatment using a filtration/holding system and/or water treatment equipment and would be recycled for reuse in subsequent operations. When this decontamination operation is complete, the piping interior can be inspected using a radiation detection instrument that is remotely manipulated through the piping. If necessary, an abrasive cleaning device can be inserted into the pipe (at each trap including vent-lines) and the pipe further decontaminated. The pipe would again be inspected for radioactivity. Any residual contamination present would be assumed to be fixed. If the lines have no detectable contamination after the above two operations, they can be plugged and abandoned in-place. If fixed contamination is still present, the lines might be excavated and removed for disposal as radioactive waste or supplemental standards would be applied to the pipes (eg, grout them solid to fix any contamination and leave in place). Because FUSRAP has successfully applied surface abrasion and scabbling to contaminated buildings in the past, they are the representative technologies retained for building contamination.

3.4.6 Institutional Controls

This response action incorporates the use of site security measures and land use restrictions as a means of eliminating possible pathways of exposure and restricting access or use of impacted media. Environmental monitoring is also included with institutional control actions. Environmental monitoring would be conducted in conjunction with all remedial alternatives to allow assessment of migration of contaminants.

Site security measures might include the use of fences, berms, and warning signs around a contaminated site to prevent unauthorized access. Land use restrictions might include restrictions through zoning or deed restrictions. All of these measures are designed to minimize the potential for direct human contact with contaminated media.

Environmental Monitoring

Environmental monitoring would be conducted in conjunction with all remedial alternatives to evaluate contaminant levels during ongoing remedial actions, to assess the effectiveness of remedial actions, and to ensure that off-site migration of contaminants is detected and mitigated. Environmental monitoring would be tailored to the selected remedial alternative so that monitoring objectives will be realized. An adequate monitoring program considers periodic sampling of media that would be affected by the continued presence of contaminants in environmental media. Periodic monitoring should be conducted of the air (for radon emissions, particulates, and external gamma radiation), sediments (to measure surface runoff impacts), and groundwater at representative locations around SLDS.

Short-term perimeter monitoring of unremediated soil areas for fugitive emissions would be implemented in order to ensure protectiveness of human health. Inaccessible soils beneath buildings and structures would be monitored by collecting radon samples inside the buildings.

Groundwater monitoring would consist of radiological and chemical analyses of samples collected from groundwater underlying and surrounding the site. Monitoring would be implemented using upgradient and downgradient wells. Groundwater monitoring is relatively independent of the selected remedial alternatives and would be required for all implemented options.

Environmental monitoring and sample analysis procedures are well-developed, reliable, and widely used at several other contaminated sites to evaluate the nature and extent of contamination. Equipment, personnel, laboratory facilities, and resources to conduct sampling and analysis are readily available.

Environmental monitoring and sample frequency for each of the remedial alternatives are described in Section 5. Appendix B covers the cost for these sampling efforts. The final monitoring plan will depend on the remediation chosen. The final detailed monitoring plan would be developed during remedial design and submitted for regulatory agency review and approval. Monitoring of areas that were remediated would continue for those areas where radioactive materials remain above unrestricted release criteria as defined in 10 CFR 20 Subpart E.

All of the institutional control technologies are retained for further evaluation.

4. DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

4.1 INTRODUCTION

This section combines the remedial action technologies retained from preliminary screening (Section 3) to form remedial action alternatives. The criteria for screening the remedial action alternatives are effectiveness, implementability, and cost. Emphasis was placed on developing alternatives that provide adequate protection of human health and the environment, achieve ARARs, and that permanently and significantly reduce the volume, toxicity, or mobility of site-related contaminants. The development of remedial action alternatives for the St. Louis site focused on those alternatives that achieve the remedial action objectives presented in Section 3.2.

4.2 DESCRIPTION OF SLDS CONTAMINATED MEDIA

The media of concern at SLDS addressed by this FS are:

- accessible soils (AS),
- buildings and structures (BS), and
- groundwater (GW).

Inaccessible soils will not be addressed by this FS because they are located under buildings or railroad beds and cannot be excavated without causing major disruptions to plant or railroad operations. Depth is not a consideration in defining inaccessible soils. Inaccessible soils will be addressed under separate documentation when an appropriate remedy that minimizes disruption of active facilities has been identified.

For the purposes of conducting a detailed analysis of remedial alternatives, the volume of inaccessible soils was calculated. However, these soils would not be removed under this remedial action. In order to minimize the disruption to owner operations and to maximize the efficiency of removal, all FUSRAP inaccessible soils at SLDS will be combined and remediated as a separate operable unit (OU). To ensure protectiveness, institutional controls would remain in place until remediation is completed.

Each medium was independently evaluated, because of the distinctive features of each medium, including the disposition of contamination. Appropriate alternatives for each medium were developed and analyzed separately. It is important that alternatives developed for each medium be compatible with each other in remediating the contamination at the entire site. The most feasible remedial alternatives for each medium were then combined to formulate remedial alternatives for all of the SLDS properties.

4.2.1 Accessible Soils

Accessible soils are soils that can be excavated without major disruptions to operations. Paved parking lots, roads and sidewalks are considered accessible. Most contaminated soil at SLDS falls into the accessible category. Old sewer lines within contaminated soil are considered accessible. The volume of these contaminated soils is estimated at 67,000 m^3 (88,000 yd^3) based on the most stringent criteria (composite criteria).

4.2.2 Inaccessible Soils

Inaccessible soils are those soils not currently accessible to excavation because excavation would result in major disruptions to commercial operations due to structures located on top of the soil. Inaccessible soils are located under portions of: Plants 1, 6, and 7 (Figure 2-1); and portions of the Norfolk and Western Railroad; St. Louis Terminal Railroad Association; and the Chicago, Burlington, and Quincy Railroad.

Excavation of inaccessible soil would require demolishing buildings, railroads, or structures. The estimated volume of inaccessible soils at SLDS considered for remediation is 25,500 m^3 (32,000 yd^3) using the most stringent criteria.

Inaccessible soils are generally subject to the same remedial options discussed for accessible soils; however, implementation of certain options is complicated by physical structures and barriers. Inaccessible soils will not be addressed in this remedial action. Inaccessible soils, because they are beneath buildings or other structures, are effectively contained as long as the structure exists and therefore the soils do not pose any immediate threat to human health or the environment. However, the inaccessible soil volume was included in the cost estimates to provide comparability across the alternatives. This approach provides a reasonable mechanism for bounding total remediation costs because the inaccessible soils must ultimately be addressed; however, it does not substantively affect the evaluation of alternatives.

4.2.3 Buildings and Structures

The SLDS buildings and structures category consists of those buildings and structures that have underlying radioactively contaminated soil resulting in external gamma exposure, within structure contamination, or radioactively contaminated structure surfaces at levels exceeding guidelines. External gamma radiation above 40 CFR 192 guidelines occurs in buildings K1E, 25, and 101. Buildings K1E and 25 also have radiological surface contamination in excess of guidelines, as defined in NRC Regulatory Guide 1.86. Surface contamination in these plants is primarily from fixed alpha and beta-gamma radiation. Building K1E is scheduled for demolition and may be removed before this remedial action begins.

4.2.4 Groundwater

Saturated conditions occur at the SLDS in the nonlithified fill and alluvial sediments, and in the bedrock. The saturated nonlithified fill and sediments are comprised of two hydrostratigraphic units: a heterogeneous upper unit composed of fill, silty clay, clay, silt and sand; and a lower unit composed of silt and sand. Only the upper unit shows isolated zones of elevated radionuclides (particularly uranium) in groundwater. A west to east cross-section of the SLDS area is provided in Figure 4-1.

The upper hydrostratigraphic unit varies from 3 to 20 m (10 to 65 ft) in thickness and has a relatively low hydraulic conductivity of 1×10^{-5} cm/sec (4×10^{-6} in/sec) (BNI 1990 and BNI 1994). The average linear groundwater velocity for this unit is estimated to range from 0.03 to 0.3 m/yr (0.1 to 1 ft/yr) (BNI 1994). In this unit, elevated uranium levels were detected in four of twelve groundwater wells. The lower hydrostratigraphic unit varies from 0 to 18 m (60 ft) and thickens in a wedge shape from west to east. No hydraulic conductivity measurements were conducted in the lower nonlithified hydrostratigraphic unit. Three constant-head packer permeability tests were conducted in the cored bedrock intervals of B16W017D (two tests) and B16W06D (one test). The average hydraulic conductivities ranged from 3×10^{-4} to 1×10^{-3} cm/sec (1×10^{-4} to 4×10^{-4} in/sec). Five wells are screened in the lower nonlithified hydrostratigraphic unit and bedrock, and none has shown elevated levels of radionuclides. Although elevated levels of radionuclides were not found in the lower hydrostratigraphic unit or bedrock, aluminum, iron, and manganese were consistently found at concentrations ranging between 10, 30, and 50 times their respective secondary MCLs (0.3 mg/L for iron, and 0.05 mg/L for manganese). This is consistent with the relatively poor natural water quality of the Mississippi and Missouri River alluvial sediments where "water from the alluvial deposits is a very hard calcium-magnesium-bicarbonate type with iron and manganese content commonly being high" (Miller 1974). In addition to iron and manganese, the total dissolved solids contents of water in the alluvial sediments is typically high, with 25 percent exceeding approximately 600 mg/L and 50 percent of samples exceeding approximately 475 mg/L (Miller 1974). The State of Missouri recommends a secondary MCL for total dissolved solids of 500 mg/L.

The movement of groundwater through the lower hydrostratigraphic sediments is eastward toward the Mississippi River, except during high water levels on the river. This is typical of the groundwater flow in the alluvium for the entire region. Groundwater discharge from SLDS into the Mississippi River is estimated at 4,500 L/d, which is only 4×10^{-6} percent of the average daily discharge rate for the Mississippi River. The saturated bedrock (Post-Maquoketa series) beneath the site has not been penetrated greater than approximately 4 m (13 ft) with a well. The flow direction of the groundwater in the bedrock is generally upward and toward the river because of the proximity of the site to the river.

The groundwater in both nonlithified units beneath the site is not considered a potential source of drinking water due to its poor water quality (high iron, manganese, and total dissolved solids). In addition, the upper hydrostratigraphic unit is not favorable for well development because the fine-grained sediments do not yield sufficient water. The bedrock units are not favorable for the development of high yield wells because yields are generally less than 50 gpm in the shallow bedrock units and the groundwater in the deeper units is typically saline (Miller 1974). Future groundwater use is considered unlikely as a result of the existing poor groundwater quality. No impacts to the water quality of the Mississippi River can be expected from any PCOCs transported to the river via groundwater due to the large flow rate of the river relative to groundwater discharge. In addition, the

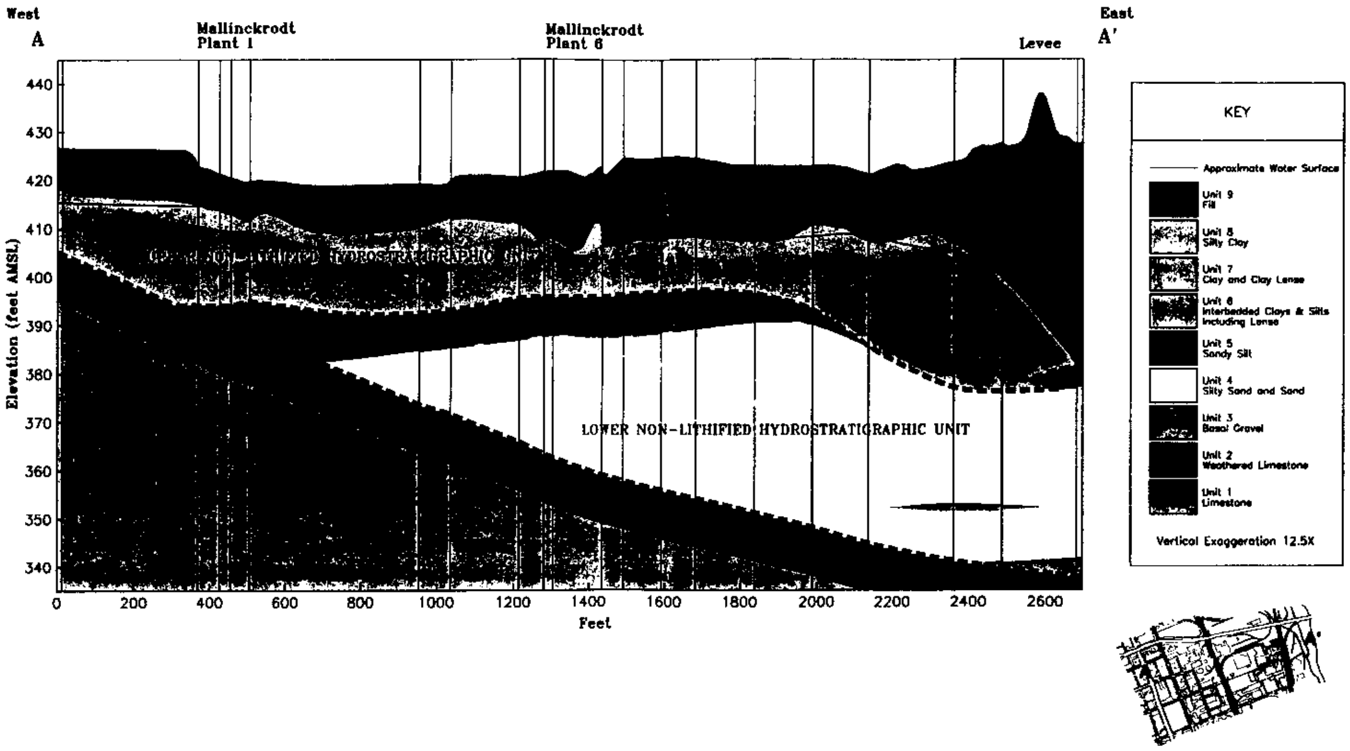


Figure 4-1. West to East Cross-Section of the SLDS Area

site is located in a area that has been heavily industrialized for over a century and the potential for continued degradation of the groundwater quality is high.

4.3 DESCRIPTION AND SCREENING OF REMEDIAL ALTERNATIVES FOR EACH MEDIUM

Preliminary remedial action alternatives have been developed for each medium at SLDS in accordance with NCP and EPA guidance and on the basis of general response actions and remedial technologies identified to meet remedial action objectives (Section 3).

Remedial action alternatives for each remedial medium were evaluated by using the criteria of effectiveness, implementability, and cost.

Effectiveness. The criterion of effectiveness measures the ability of each alternative to effectively protect human health and the environment by reducing the toxicity, mobility, or volume of contaminants. Elements of effectiveness include short- and long-term effectiveness. Short-term effectiveness involves reducing existing risks to the community and workers during implementation of remedial actions, the ability of an alternative to meet cleanup guidelines, and the time required for the remedial alternative to achieve the desired result, including the potential length of exposure to which the local public may be subjected. Long-term protectiveness addresses the magnitude of residual risk and the long-term reliability associated with the alternatives. The alternatives were also evaluated for their effectiveness in preventing future exposure to residual contamination.

Implementability. Each alternative was evaluated in terms of implementability, including technical feasibility, administrative feasibility, and availability of necessary remedial materials, equipment, and work force. The assessment of short-term technical feasibility considered the ability to construct the given technology and the short-term reliability of the technology. Long-term technical feasibility factors considered include the ease of undertaking additional remedial action if necessary, of monitoring the effectiveness of the given remedy, and of operation and maintenance. Administrative feasibility for implementing a given technology was evaluated by reviewing the ability to obtain approvals from other agencies, the likelihood of favorable community response, and the need to coordinate with other agencies.

Cost. The cost criterion includes relative capital costs for materials and operations and maintenance (O&M) rather than detailed estimates. O&M costs are assumed for a 30-year period for remedial alternatives where hazardous substances, pollutants, or contaminants that may pose a threat to human health or the environment remain at the site. Costs for each alternative are rated on the basis of engineering judgment as high, moderate, or low by comparison to the costs of similar remedial alternatives.

The following is a description and evaluation of remedial alternatives by remedial unit.

4.3.1 Accessible Soils

Accessible soil remedial alternatives are:

- Alternative AS1 – No Action,
- Alternative AS2 – Institutional Controls and Site Maintenance,
- Alternative AS3 – Containment,
- Alternative AS4 – Excavation Followed by Off-site Disposal, and
- Alternative AS5 – Excavation Followed by Treatment and Off-site Disposal.

A brief description of each of these alternatives for accessible soils follows.

4.3.1.1 Alternative AS1 – No Action

The no-action alternative was developed to provide a baseline for comparison with other alternatives, as is required under CERCLA. This alternative provides no additional protection of human health and the environment. No remedial actions would be taken to reduce, contain, or remove contaminated soils. Only ongoing environmental monitoring would be conducted. No effort would be taken to prevent or minimize human and environmental exposure to residual contaminants onsite. Off-site migration of contaminants would not be mitigated under the no-action alternative.

Effectiveness. Potential effects on human health and the environment are presented in the BRA (ANL 1993). The BRA showed that the radiological risk for current use at the downtown properties is within EPA's acceptable risk range of 10^{-6} to 10^{-4}, except for the SLDS construction worker if worker protection standards are not in place. There would be no change in the current risk to onsite workers or the community because no remedial actions would be implemented. However, future uses could lead to unacceptable risk because this alternative provides no controls to prevent exposure to contaminants and no long-term management measures. Under the no-action alternative, there would be no reduction in the mobility, volume, or toxicity of site-related contaminants.

Implementability. Implementability is immediate because no additional remedial actions are taken.

Cost. This alternative is low cost and imposes no additional costs beyond those for continuing the current environmental monitoring program for at least 30 years (time frame used in CERCLA for evaluating sites).

4.3.1.2 Alternative AS2 – Institutional Controls and Site Maintenance

This alternative uses a combination of land-use restrictions and maintenance measures to prevent significant human exposures. Institutional controls will either prevent or limit access to contaminated areas. Institutional controls applicable to accessible soils include land-use restrictions and site security measures. Security is presently maintained at Mallinckrodt Inc. These security measures would constitute the means of restricting access. Barriers such as fencing and posting signs would be employed at other areas such as the City Property and accessible areas at the vicinity properties. Environmental monitoring will be conducted to ensure continued protectiveness of controls.

Land use restrictions could be used at the site. All properties at SLDS, including vicinity properties, are currently subjected to zoning restrictions thus precluding transition from industrial land use to residential land use. Zoning restrictions would continue to be enforced through zoning authorities.

Effectiveness. This alternative increases protection of human health and the environment over baseline conditions by limiting direct access to the site by means of deed or land-use restrictions and site security measures. Although there would be no reduction in volume, toxicity, or mobility of contaminants in the soil, future risk would be maintained at acceptable levels as a result of access restrictions. That is, acceptable risk conditions would be maintained for the St. Louis site properties in the future by placing controls over future property uses. USACE would not be able to control access and use of the land on properties not owned by USACE with the use of institutional controls.

Implementability. Land use restrictions would require coordination among various entities including the Federal Government, city of St. Louis, MDNR, and private property owners. Environmental monitoring and sample analysis procedures are well developed, reliable, and widely used to evaluate the nature and extent of contamination. Monitoring equipment, personnel, and laboratory facilities required to conduct sampling and analysis are readily available.

Cost. The costs for implementing the institutional controls and site maintenance are low for both initial capital and O&M costs. Long-term environmental monitoring, which includes a full-time maintenance and service individual, constitutes the O&M costs. Environmental monitoring is assumed to continue as long as residual risk constitutes an unacceptable risk to human health or the environment. O&M costs include sampling personnel, equipment, expendables, and analysis.

4.3.1.3 Alternative AS3 – Containment

This alternative incorporates containment, institutional controls, and environmental monitoring to reduce further spread of contaminants and reduce potential for direct exposure. Several options were considered for the containment alternatives. Factors such as current business activity, the presence of buildings, property acquisition, site maintenance and monitoring requirements, site geography, site geology, and risk of exposure or further contamination were evaluated to determine if capping in place or consolidation (partial or complete) of soils at a single site for containment best achieved remedial objectives.

The best containment strategy for accessible soils was identified as excavation of accessible soils and consolidation and capping of excavated soils at a consolidated site, followed by institutional controls and environmental monitoring at the capped area. This containment approach was considered the best because it reduces the number of properties containing contaminated soils to one central location. Under this alternative, all accessible soils at SLDS would be excavated and consolidated at one location. Potential locations include the city property or

Plant 2. The consolidated soils would then be capped. For costing purposes the cap was assumed to consist of all-natural materials (no synthetic liners or other man-made materials) in a low permeability liner and cover. An advantage of all-natural material is the absence of degradation. Capping prevents direct contact of contaminants with humans or the environment. It requires both institutional controls to limit use of or access to the site and environmental monitoring to detect breaching of the cap and contaminant migration. USACE would acquire the property, build the cap, and provide site maintenance and monitoring.

Effectiveness. This alternative would protect human health and the environment. It increases protection of human health and the environment over baseline conditions and meets remedial action objectives for accessible soils. Once installed, the cap would reduce the potential for direct contact (absorption, ingestion, or inhalation) and minimize potential exposure to external gamma radiation and radon gas. The cap would minimize water infiltration and mobilization of contaminants by leaching from soil to groundwater. During implementation, possible short-term, increased risk from fugitive dust emissions would be controlled by mitigative measures and proper safety procedures.

Implementability. No technical problems are anticipated that would limit the implementability of this alternative. Capping is a well-established technology. Some clearing and grubbing, rerouting of utilities, and other site preparation activities would be required before the cap is constructed. Traffic may need to be rerouted when excavating under roadways. Excavation of soils from vicinity properties also can be accomplished fairly easily with implementation of site controls. Site monitoring would be required during excavation. Temporary roads may have to be constructed, but this work can be easily accomplished. Transportation would be coordinated among local agencies, MDNR, and USACE.

Coordination among MDNR, EPA Region VII, and USACE would be required to monitor contaminated media, ensure effectiveness of the capping system, and manage the site. Permits to construct an engineered cap should not be difficult to obtain. Transferring ownership of the containment area should be achievable but would involve compensation to the owner at fair market value for the property. Adequate space exists to consolidate and cap the soil at either the City Property between the Levee and Mallinckrodt Inc. or at Plant 2 where the buildings were recently demolished leaving a large unused area.

Cost. This alternative would have high capital but moderate O&M costs compared with other alternatives. The capital costs include land purchase, soil excavation, transportation, and installation of a clay cap. O&M costs would be a function of the degree of activity needed to address soil subsidence for the containment facility. Long-term environmental monitoring and cap maintenance constitute most of the O&M costs. O&M costs include labor costs for cap and cover maintenance, sampling personnel, equipment, expendables, and sample analysis. Monitoring is assumed to continue for as long as the media under the cap requires to maintain protection of human health and the environment.

4.3.1.4 Alternative AS4 – Excavation Followed by Off-site Disposal

This alternative comprises excavation and off-site disposal of accessible soils exceeding the criteria established for the cleanup. Standard techniques for excavation, dust control, soil erosion control, and other health and safety precautions would be used at the sites.

For this alternative, there are several disposal options:

- waste disposal facility licensed for radioactive waste,
- placement in a solid waste landfill, and
- placement in a Subtitle C landfill.

The selection of the disposal alternative will be made on the basis of waste classification. If the material is determined to be regulated, it must be disposed in an authorized waste disposal facility.

Effectiveness. This alternative is protective of human health and the environment. It increases protection to human health and the environment over the previously outlined alternatives, and it achieves remedial action objectives. Compliance with ARARs would be achieved because derived guidelines for radioactive residuals in soil would reduce future residual risk to acceptable levels. Exposure from fugitive dust, radon gas, external gamma radiation, contaminants leaching into groundwater, and contaminated surface water runoff would be greatly reduced because the source of contamination would be removed. Short-term risks, including non-radiological occupational injuries and risk of fatalities and transportation risk would increase as the volume of soil being handled and moved increases. During implementation, there would be possible short-term risk from fugitive dust emissions, which would be readily manageable via implementation of a health and safety plan. Air quality could be adversely affected by release of particulates during excavation. Mitigative measures such as dust suppression methods and proper safety procedures would be implemented to minimize any increased risk to the community or to onsite workers during implementation.

Implementability. Soil excavation uses readily available resources and conventional earth-moving equipment. Some ancillary construction of temporary roads, a staging area for loading and unloading, soil erosion control, excavation dewatering, and additional clearing and grubbing may be necessary. Transportation and disposal of wastes are routine activities, but they must be coordinated to minimize adverse environmental and logistical effects.

The administrative feasibility of this alternative would require coordination of remedial activities. Site security measures during excavation and other remedial activities would require coordination with local agencies.

Transportation and disposal of wastes would utilize dump trucks or rail cars. If soil were moved out of state, coordination would need to be obtained ahead of time to allow the waste to cross state lines. Because not all rail lines and highways can be used to transport waste material, a shipping route would need to be carefully laid out and an emergency response procedure developed.

Cost. This alternative has high capital and low O&M costs compared with other alternatives. High capital costs would be incurred from excavating transporting, and disposing of contaminated accessible soils. Distance to the disposal facility and type of disposal facility are key elements that will affect the costs.

4.3.1.5 Alternative AS5 – Excavation followed by Treatment or Volume Reduction and Disposal

Alternative AS5 would encompass all the elements of Alternative AS4, except that treatment of excavated soil would follow excavation and precede disposal. Soils would be treated onsite by using a soil sorting or enhanced soil washing process. The treated soils would be disposed onsite as backfill in the excavated areas. Treatment residuals, which would contain significantly higher concentrations of radionuclides than the untreated soil, would be sent to an appropriate disposal facility.

Effectiveness. The effectiveness of the excavation and disposal portion of this option is identical to that presented for Alternative AS4. The effectiveness of soil treatment is presented here. Two primary treatment technologies have been considered potentially applicable to the St. Louis Downtown soil, soil sorting and soil washing.

Treatability tests conducted with SLAPS and HISS soil found that although soil washing could significantly reduce contaminant concentration in treated soil, the very low criteria for Th-230 and Ra-226 in effect at the time could not be met. No treatability tests on St. Louis soils have been conducted to date with soil sorting equipment. Treatability studies using SLAPS and HISS soils have limited applicability to SLDS. The soil in the northern section of the county where SLAPS and HISS are located contains high levels of clay. Clay tends to sorb radionuclides making separation difficult. SLDS, on the other hand, contains a fill layer from the surface to a depth of about 4 m (13 ft) over most of the site consisting of unconsolidated brick, reinforced concrete, organic material, coal slag, sand and silt. The materials comprising the fill layer at SLDS, which contains most of the radioactive contaminants, are likely to be far more amenable to treatment technologies than the soil used in the treatability studies. While treatment could significantly reduce the volume of waste for disposal, treatability studies would need to be performed before the effectiveness can be adequately evaluated.

Implementability. Soil excavation would be conducted as described under Alternative AS4. Using a single treatment unit to conduct onsite soil treatment is possible. The unit could be located at Plant 2 where the removal of contaminated buildings has provided a suitable area for setting up a treatment unit for processing. Applying the treatment step to the remediation process assumes that the treated soil pile can be directly placed back into the site as backfill.

Cost. Even though accurate cost figures cannot be derived before an effective treatment option has been identified, one can expect that this alternative has high capital and low long-term O&M costs.

4.3.1.6 Summary

The formulation and screening of accessible soil alternatives (using the criteria of effectiveness, implementability, and cost) results in retaining all alternatives for further evaluation and combination with alternatives for other remedial units to yield site-wide alternatives discussed in Section 4.4. Alternative AS5, although retained, contains a great deal of uncertainty in treatment applicability to SLDS soils and cost savings. However, if a treatment or volume reduction technology can be demonstrated to be both applicable and cost effective prior to implementation of the remedial action and if regulator approval to return the treated soil can be obtained, treatment could potentially be implemented in conjunction with excavation alternatives. Treatment is therefore retained as a conditional part of the remedy and may be added as an adjunct to alternatives involving excavation.

4.3.2 Buildings and Structures

The alternatives developed for remediation of the contaminated SLDS buildings and structures are:

- Alternative BS1 – No Action;
- Alternative BS2 – Institutional Controls and Site Maintenance;
- Alternative BS3 – Containment;
- Alternative BS4 – Decontamination and Surface Restoration;
- Alternative BS5 – Dismantlement and Disposal of Debris; and
- Alternative BS6 – Decontamination, Dismantlement, and Disposal of Debris.

A brief description of the alternatives for the buildings and structures follows.

4.3.2.1 Alternative BS1 – No Action

The No-Action alternative was developed to comply with CERCLA regulations and provides a baseline for comparison with other alternatives. Under this alternative, no remedial actions beyond current activities would be implemented. All equipment, materials, and waste would remain in place, and human exposure to radionuclides would be unchanged from current conditions. Under this alternative, periodic monitoring of routine building maintenance and site security would continue.

Effectiveness. This alternative neither reduces any current risks nor prevents any future risks to human health and the environment. ARARs could only be met by restricting access to areas exceeding surface criteria. Increased exposure to contaminants is likely to increase as buildings deteriorate. It is also plausible that the volume of contaminated material would increase due to building deterioration. There would be no significant reduction in volume, toxicity, or mobility of contaminants if this alternative is implemented.

Implementability. Implementability of this alternative would be immediate because no additional materials or personnel would be required.

Cost. This alternative has low O&M and capital costs compared to other alternatives, and it imposes no additional costs beyond those for continuing current activities. The present environmental sampling program constitutes the O&M costs.

4.3.2.2 Alternative BS2 – Institutional Controls and Site Maintenance

This alternative provides additional site security and signs warning of possible radiological exposure as well as continued monitoring. It also includes health physics support for radiological waste management. Land-use restrictions may be an additional means of institutional control if the facilities are decommissioned.

Effectiveness. This alternative would comply with surface criteria ARARs and reduce risk from exposure to external gamma radiation by using institutional controls to restrict building access, but the future risk would remain. Because no treatment process would be used to contain or remove the contamination, no significant reduction in contaminant volume, toxicity, or mobility would be realized if this alternative is implemented. Institutional controls consisting of security measures already limit access at Mallinckrodt Inc.

Implementability. Instituting any new security, postings, and an upgraded monitoring program is implementable. Security, postings, monitoring, sample collection, and analysis procedures are established, reliable, and widely used at a number of similar sites. Additional site security consisting of either signage or security personnel would be negotiated.

Cost. The capital and O&M costs for this alternative are low compared to other alternatives. Long-term environmental monitoring constitutes all of the O&M costs.

4.3.2.3 Alternative BS3 – Containment

This alternative seeks to contain contaminants by surface sealing and/or radon control measures and environmental monitoring at contaminated buildings. Surface sealing involves covering a contaminated surface with a sealant to prevent releasing radionuclides into the environment. Surface containment would effectively reduce alpha and beta emissions but would have essentially no effect on gamma radiation. However, with appropriate institutional controls, this alternative can achieve remedial objectives for buildings and structures. If necessary, radon control measures would be used in conjunction with sealing to prevent radon contamination within the buildings. Radon control measures are discussed in Section 3.4.3.

Effectiveness. This alternative would provide only short-term protection to human health or the environment because surface seals degrade over time. ARARs would be met by reduction of emissions from surface contamination. Containment through surface sealing reduces direct contact with residual surface contamination, controls mobility, and prevents further spread of contaminants. As long as the sealing material is maintained at design and operating conditions, remedial action objectives would be achieved. Although sealing would reduce exposure to contaminants, it would not be effective for external gamma radiation and contamination would remain. However, institutional controls would further reduce exposure by limiting access to the building through site security and deed restrictions. Radon control measures would reduce exposure if radon gas is generated from underlying soils. Applying the sealants inside the buildings creates no risk to the community. Mitigative measures such as temporarily relocating site employees and using proper safety protocols would minimize the risk to workers.

Implementability. Surface sealants such as paint, resin, and plastic as well as physical barriers such as plastic sheeting, are easily applied and are used extensively in the construction industry, but generally on new or well-prepared surfaces. The poor condition of most surfaces at SLDS would involve surface preparation that, in most cases, would remove the contamination as described in BS4. The implementability of institutional controls would be identical to the discussion in Section 4.3.1.2. Coordination with Mallinckrodt Inc. would be required to minimize disruption of plant activities.

Cost. This alternative would have low to moderate capital and low O&M costs compared to other alternatives. The capital costs include sealing surfaces and possibly installing radon control measures within contaminated buildings. Environmental monitoring constitutes all of the O&M costs and would continue for a minimum of 30 years.

4.3.2.4 Alternative BS4 – Decontamination, Surface Restoration, and Disposal

Under this alternative, physical or chemical decontamination technologies would be implemented to remove radioactive surface contamination. After decontamination, surfaces would be restored to their original condition, and the buildings without inaccessible soils could be released for unrestricted use. Waste streams generated from decontamination would be collected for treatment and disposal.

Effectiveness. This alternative would protect human health and the environment, comply with ARARs, and it would achieve remedial action objectives for buildings and structures. Although the contaminant source would be removed from most surfaces, decontamination may not be completely effective on some surfaces where access is limited. Consequently, surfaces having limited access for decontamination equipment would need to be removed and replaced (see dismantlement under BS5). Under this alternative, no long-term maintenance would be required because the contaminant sources would be removed from the buildings. This alternative would not be effective at controlling radon gas. Radon control measures are discussed in Section 4.3.2.3. Potential short-term risk to workers and employees would be mitigated by adhering to the health and safety plan.

Implementability. Physical and chemical decontamination methods are implementable. The decontamination of buildings and structures requires specialized equipment and trained personnel that are all commercially available. The choice of decontamination technology is based on the surface to be decontaminated and the type and level of radioactivity on the surface. Waste streams generated from decontamination would be contained and disposed of as radioactive waste. Monitoring would be conducted during implementation to ensure protection of remedial workers.

Cost. The costs of decontamination and restoration are moderate in capital and low in O&M costs compared to similar alternatives. Environmental monitoring would be conducted during decontamination activities. Long-term O&M costs would include monitoring for radon gas only.

4.3.2.5 Alternative BS5 – Dismantlement and Disposal of Debris

This alternative, along with Alternative BS6, was originally identified as demolition and disposal in the ISA (SAIC 1992). Subsequent evaluation has indicated dismantlement of buildings more adequately describes the activities that would occur under these alternatives.

This alternative constitutes dismantling contaminated surfaces of buildings and structures and disposing of the resulting debris. Dismantling any particular portion of a building or structure could be partial or total, depending on the extent of contamination. Disposal alternatives for debris depend on the levels of contamination. This process would reduce contamination on the surfaces to guidelines for residual radioactive contamination and would thereby reduce the potential for exposure. After segregating radioactive debris from non-radioactive debris, it may be feasible to transport non-radioactive debris to a permitted disposal facility. The appropriate requirements, as cited in Section 3.2.1, will be followed as they apply to a waste stream. Building materials which do not meet the surface criteria may, following crushing to a soil like material, meet volumetric criteria and could be used as backfill around the site. If regulatory approval could be obtained.

Under this alternative, USACE would defer cleanup of inaccessible soils into a separate operable unit.

Effectiveness. This alternative is protective of human health and the environment, complies with ARARs, and achieves remedial action objectives for buildings and structures. Any short-term risks incurred during implementation of this alternative would be controlled by mitigative measures and proper safety procedures.

Implementability. This alternative is technically implementable. Dismantling buildings and structures uses commercially available equipment and requires trained personnel. Dismantlement technology is reliable and frequently used in the construction industry. However, this alternative would be difficult to implement because of ongoing plant operations.

Cost. This alternative includes high capital costs, compared to other alternatives, for dismantlement followed by restoration of buildings and disposal of contaminated building structures. Environmental monitoring during demolition would constitute the only O&M costs.

4.3.2.6 Alternative BS6 – Decontamination, Partial Dismantlement, and Disposal

This alternative combines elements of Alternative BS4 (decontamination techniques) and Alternative BS5 (dismantlement techniques). It involves decontaminating the surfaces of the buildings and partial dismantlement of minor structures that cannot be decontaminated. This process would reduce contamination on the surfaces to guidelines for residual radioactive contamination and would thereby reduce the potential for exposure. Debris below radiological criteria may be reduced in volume and transported to a permitted waste disposal facility or used as backfill, while those materials exceeding radiological criteria would be sent for appropriate waste disposal.

Effectiveness. This alternative protects human health and the environment and complies with ARARs, as described in Alternatives BS4 and BS5 (Sections 4.3.3.4 and 4.3.3.5), by reducing the contamination in affected buildings and structures below guidelines. Prior treatment of contaminated surfaces may qualify building debris for disposal at a permitted disposal facility, if required.

Implementability. The physical and chemical decontamination and removal of parts of buildings and structures use commercially available equipment and trained personnel. The choice of decontamination technology would be based on the type of building/structure surface and the level of contamination. Decontamination of building and structure surfaces can be implemented with minimal disturbance of ongoing activities, while dismantlement would be disruptive.

Cost. The cost of this alternative includes high capital costs for decontamination, dismantling, disposal, and subsequent reconstruction of the buildings. The capital costs may be lower than Alternatives BS4 and BS5, however, because it can take elements from both of these alternatives to create the most cost effective combination environmental monitoring would constitute the only O&M costs.

4.3.2.7 Summary

The evaluation and screening of each remedial alternatives for buildings and structures is summarized below.

Alternative BS1 is retained because it represents the no-action alternative for buildings and structures. Alternative BS2 is retained, even though it would require long-term actions, because it would be protective. Alternative BS3 will not be considered further because it would not provide long-term protection to human health and the environment. Alternative BS3 would be no more effective than institutional controls because sealed surfaces degrade over time. The option for dismantlement (Alternative BS5) alone without any decontamination will not be considered for further evaluation. Dismantlement activities for all contaminated surfaces would have significant effects on ongoing plant activities; therefore, they would be difficult to implement. In addition, the costs of implementing this option would be high because all dismantled building surfaces would have to be reconstructed. Alternative BS6, which includes Alternative BS4, has been retained for further consideration. After decontamination has been completed, the level of residual radioactivity on building surfaces would comply with standards. Therefore, this alternative is potentially effective, easily implemented, and would meet remedial action objectives after implementation.

The option of dismantling buildings that have nonremovable contamination (ie, dismantlement) and decontaminating all removable surfaces has significant advantages over decontamination alone because all surfaces would be below guidelines for residual radioactive contamination. The cost is higher than that for the decontamination alternative because dismantled building structures would have to be reconstructed. The alternatives remaining for the buildings and structures will be combined with other alternatives to yield the site-wide alternatives.

4.3.3 Groundwater

The alternatives identified for groundwater remediation are:

- Alternative GW1 – No Action;
- Alternative GW2 – Institutional Controls and Site Maintenance;
- Alternative GW3 – Containment (Slurry Walls and/or in Situ Grouting); and
- Alternative GW4 – Removal of Concentrated Source Material, Extraction, Treatment, and disposal.

A brief description of remedial alternatives for contaminated groundwater follows.

4.3.3.1 Alternative GW1 – No Action

Under this alternative, no remedial actions other than routine monitoring and security measures would be implemented. Groundwater monitoring activities would continue as long as the PCOCs in groundwater remained above regulatory guidelines. Groundwater monitoring results would continue to be reported to appropriate agencies.

Effectiveness. This alternative neither reduces any current risks nor minimizes any future risks to human health or the environment. Because COCs could remain in groundwater above guidelines, current and future risk to human health exists if groundwater from the upper nonlithified hydrostratigraphic unit is consumed. Current risk is minimal because groundwater in the upper hydrostratigraphic unit is not a source of drinking water, is of very low yield, and is not used for other purposes. Considering the extensive surface water sources for drinking water and the poor groundwater quality, the likelihood of significant future risk seems low, but higher risks due to groundwater consumption cannot be fully ruled out, although the chemical constituents in groundwater pose a higher risk than the radiological constituents (ANL 1993). No reduction in volume, toxicity, or mobility of groundwater containing PCOCs through treatment would be achieved from a no-action alternative. However, processes such as ion exchange reactions and physical filtration can reduce the potential for off-site migration. PCOCs that have an affinity to sorb onto the aquifer material can be exchanged with cations such as calcium, magnesium, sodium, and potassium that are commonly associated with clayey soils that occur below the fill at SLDS. For example, dissolved uranium could replace naturally occurring calcium associated with clay. This ionic exchange would bind the uranium to the clay and inhibit the ability of uranium to migrate in groundwater.

Any PCOCs entering the river from SLDS would be diluted below any applicable standards and likely below the ability to detect them. Groundwater contaminants underlying SLDS would not adversely impact human health because the area is industrialized and does not afford access to groundwater beneath the site, and the PCOCs primarily remain near the soil sources in the upper hydrostratigraphic unit which, under any condition, is not a suitable unit for obtaining potable water because of its poor water quality and low yield. Migration of PCOCs to the lower hydrostratigraphic unit is unlikely because the upper hydrostratigraphic unit is relatively impermeable at its base and because "artesian or leaky artesian conditions prevail throughout most of the Mississippi River alluvium" (Miller 1974).

Implementability. Implementability of this alternative would be immediate because no additional materials or personnel would be required.

Cost. This alternative imposes no additional costs beyond those for existing activities. A routine environmental monitoring program would continue for a minimum of 30 years with five-year reviews.

4.3.3.2 Alternative GW2 – Institutional Controls and Site Maintenance

This alternative uses groundwater use restrictions to prevent human exposure to groundwater containing PCOCs. Implementation of this alternative would ensure that site groundwater will not be available for future use. Groundwater is not currently a source of drinking water, and its potential future use, though unlikely because of poor water quality and low yield in the upper hydrostratigraphic unit, could be prohibited in affected areas by denying any permits to install new wells.

Effectiveness. As described in the no-action alternative, the fate and transport of contaminated particles in groundwater is naturally controlled by the low permeability of the soils in the upper unit and aquitard. Off-site migration would be extremely slow and toward the Mississippi River. Institutional controls could be used to prohibit groundwater consumption. Thus, institutional controls would effectively prevent exposure to contaminants in groundwater.

Implementability. Monitoring would be used to evaluate any migration or spread of contamination. Institutional controls would also be considered.

Cost. Capital costs are low compared to other alternatives but could change to moderately high. This alternative imposes moderate O&M cost to maintain a long-term environmental monitoring program. Environmental monitoring would continue for a minimum of 30 years with five-year reviews.

4.3.3.3 Alternative GW3 – Containment

Containment consists of installing vertical and/or horizontal subsurface barriers to isolate the groundwater containing PCOCs and associated soils from interaction with groundwater infiltration from the ground surface. This alternative would be implemented through the construction of vertical slurry walls, the construction of horizontal barriers through grout injection, capping, dewatering through interceptor drains and sumps, and environmental monitoring. The slurry would consist of soil mixed with bentonite. Groundwater containing PCOCs and associated soils underlying the sites would be effectively isolated from interaction with adjacent groundwater through construction of lateral slurry wall barriers. The site could be covered with a multilayer cap made of low permeability material at the surface to reduce the infiltration of precipitation within the slurry wall boundaries. Isolation of groundwater containing PCOCs and associated soils beneath buildings and structures at SLDS would be achieved through grout injection beneath the structures. Environmental monitoring would be conducted to assess the effectiveness of the containment system over time. Groundwater containing PCOCs and associated soils would remain in place under this alternative.

Effectiveness. Calculations have shown that with a minimum retardation factor of 100 factored into a maximum linear velocity of 7.8 m/yr (26 ft/yr), PCOCs identified in the upper hydrostratigraphic unit at SLDS would have a slow solute migration rate of 0.078 m/yr (0.26 ft/yr) (BNI 1994b). Slow migration is consistent with the fact that groundwater containing PCOCs has not been found outside of the areas of contaminated soil after nearly half a century. Because of the nature of the PCOCs, subsurface barriers would have to be effective for a long period of time. The performance of slurry walls has not been documented by long-term field studies and the ability of these barriers to maintain their structural integrity over a long period of time is an unknown. If combined with a cap, slurry wall use would provide a viable containment. The option of capping is addressed under the accessible soils remedial unit.

The effectiveness of a slurry wall at SLDS would also be compromised because of the numerous point sources of soil contamination, the large areal extent of the site, the high permeability of the soils underlying the site into which the barrier must be keyed, the questionable integrity of confining layers underlying the site, and the increased depth to bedrock on the western portion of the site. Grout injection beneath buildings and structures at SLDS could be implemented using angled grout pipe and patterned areal injection. Capping would be ineffective at SLDS because buildings and roadways cover most of the site.

The option of dewatering through interceptor drains and sumps would not be effective due to the low permeability and heterogeneity of the subsurface soils.

Implementability. Grout injection would be difficult due to the limiting geologic properties of the soils at the sites. Lack of a suitable barrier to key into also negates this containment approach for the SLDS site. Environmental monitoring during and after construction can be readily implemented. Site work for this alternative would not be a routine project because special equipment and personnel would be required.

Cost. Capital costs for implementing this alternative would be high due to the limited availability of qualified contractors specializing in slurry wall construction and grouting. O&M costs include building and roadway maintenance, groundwater control in the encapsulated areas, groundwater disposal, long-term environmental monitoring, and site access controls.

4.3.3.4 Alternative GW4 – Removal of Concentrated Source Material, Extraction, Treatment, and Disposal

This alternative includes removal of concentrated soil source material, groundwater extraction, treatment, discharge of treated water, institutional controls, and environmental monitoring. Removal of concentrated soil source material is identical to excavation of accessible soil and is described under Section 4.3.1.4, Alternative AS4. Groundwater would be extracted from the upper hydrostratigraphic unit by means of well points or a drainage interceptor trench. Extracted groundwater would be routed to onsite treatment plants. Environmental monitoring would continue and institutional controls would be implemented until remedial objectives are met. The collection and treatment of groundwater during soil excavation is not included in this alternative and may be implemented as a secondary measure.

Pretreatment technologies would include precipitation, flocculation, sedimentation, filtration, evaporative recovery, filter backwashing, clarification, and sludge dewatering. Groundwater treatment would consist of air stripping, activated carbon adsorption, and ion exchange. Based on well development and hydraulic testing data that were collected during site characterization, studies suggest that for groundwater extraction and treatment evaluations, an average yield of just over 1 gpm should be assumed. With this low yield, numerous groundwater extraction wells would need to be placed very close to one another to have any significant effect on groundwater quality.

For this alternative, there are five combination treatment and discharge options:

- precipitation, flocculation, and filtration followed by air stripping and activated carbon adsorption and discharge to a surface water body;
- precipitation, flocculation, and filtration followed by air stripping and activated carbon adsorption and disposal to a POTW;
- air stripping followed by activated carbon adsorption, ion exchange, and disposal to a surface water body;
- air stripping followed by activated carbon adsorption, ion exchange, and disposal to a POTW; and
- precipitation and flocculation followed by air stripping, ion exchange, and disposal to a surface water body.

For all treatment options, it is assumed that sludge generated from treatment operations would be disposed of in the same manner as soils containing PCOCs.

Effectiveness. EPA, Oak Ridge National Laboratory (ORNL), the Congressional Office of Technology Assessment, and other national institutions completed separate evaluations of the performance of groundwater extraction systems. The results were presented at the National Groundwater Association Conference on Aquifer Restoration: Pump and Treat and Alternativesheld in Las Vegas, Nevada in September 1992 (NGWA 1992). All these studies have concluded that aquifer heterogeneity or the presence of relatively insoluble compounds inhibits the effectiveness of pump-and-treat remediation. Pump-and-treat technologies are limited by subsurface conditions and characteristics of the PCOCs. The effectiveness of pump-and-treat technologies is limited by highly heterogeneous subsurface (ie, highly stratified geologic systems with multiple layers of coarse and fine-grained materials) and low-permeability subsurface material. These subsurface conditions exist at SLDS. These are also the conditions which tend to minimize the potential for migration of PCOCs.

The characteristics of contaminants also influence the effectiveness of pump-and-treat technologies. Uranium, the primary PCOC in groundwater at SLDS, is characterized as having low solubility in water and high sorbing affinity to geologic materials. Restoring the upper hydrostratigraphic unit is unlikely without source control. Source control requires excavation or remediation of soils where high concentrations of the PCOCs (primarily uranium) exist. Removal of concentrated soil source material is an element of this alternative, is accomplished under Alternative AS4, and would be effective in eliminating or substantially reducing groundwater contamination.

Implementability. Adequate space exists to construct all the anticipated process facilities (ie, extraction wells, buildings). Some site preparation would be required. Materials and qualified vendors needed to implement this alternative are readily available. Coordination with other agencies would be required to implement a long-term groundwater monitoring program. In addition, coordination with appropriate authorities and compliance with the substantive requirements would be needed for POTW discharge or for an NPDES permit to discharge into surface water. Implementability for removal of source material is covered under Alternative AS4.

Cost. The costs for the extraction, treatment, and disposal of treated waste water portions of this alternative are high for capital and O&M costs in comparison to other alternatives. Capital costs include designing and installing groundwater extraction and treatment systems and treated groundwater disposal costs. Groundwater monitoring and treatment facilities operations would be included in the cost of O&M. The cost of removal of source material is described under Alternative AS4.

4.3.3.5 Summary

Alternatives GW1 (no action), GW2 (institutional controls), and the portion of GW4 that addresses removal of concentrated soil sources of COCs were retained for detailed analysis. Although the no-action alternative (Alternative GW1) may not be protective of human health and the environment under future risk scenarios, it was retained for detailed analysis as required by the NCP. Alternative GW2 was also retained for detailed analysis because it would protect human health and the environment, is easily implemented, and would be cost effective. GW3 is not considered further because of the uncertainty associated with the effectiveness of subsurface barriers; the ineffectiveness of grouting technology in the SLDS aquifer; and the existence of effective retardation of contaminant movement in the groundwater. The extraction, treatment, and disposal of treated water portions of Alternative GW4 were eliminated from further consideration on the basis of effectiveness and cost (Section 3.2.1.3). However, removal of concentrated soil sources of the COCs (primarily uranium) was retained and is included as part of the excavation activities associated with Alternative AS4. The costs associated with the extraction and treatment of groundwater in Alternative GW4 would be much greater than Alternative GW1 or Alternative GW2 and no more effective. Collection and treatment of groundwater during soil excavation may be necessary if soil is excavated from beneath the groundwater table.

4.4 DEVELOPMENT OF ALTERNATIVES

In this section, alternatives are formulated using retained remedial unit alternatives. The overall objective of the site-wide alternatives is to protect human health and the environment for the entire downtown St. Louis site. Site-wide alternatives were assembled to cover a wide range of options that best address the remedial units while meeting the overall objective.

Media specific alternatives retained for detailed analysis are summarized in Table 4-1. Following the preliminary screening process, retained alternatives were organized into site-wide alternatives described below (see also Table 4-2). Site-wide alternatives are comprised of a range of options or media specific alternatives that address all contaminated media at the SLDS. The range of site-wide alternatives includes a no-action alternative, a limited action alternative, a containment alternative, and alternatives involving partial and complete excavation of soil source material.

Table 4-1. Summary of Selected Alternatives for Each Medium at the SLDS

Accessible Soils	
Alternative AS1	No Action
Alternative AS2	Institutional Controls and Site Maintenance
Alternative AS3	Containment (Consolidation and Capping)
Alternative AS4	Excavation and Disposal (includes GW4 soil source removal)
Alternative AS5	Excavation and Treatment
Buildings and Structures	
Alternative BS1	No Action
Alternative BS2	Institutional Controls and Site Maintenance
Alternative BS6	Decontamination, Partial Dismantlement, and Disposal
Groundwater	
Alternative GW1	No Action
Alternative GW2	Institutional Controls and Site Maintenance

Table 4-2. Summary of Media Specific Alternative Composition of the Site-wide Alternatives

Site Wide Alternative	Media Alternative Elements
1	AS1 + BS1 + GW1
2	AS2 + BS2 + GW2
3	AS3 + AS5 + BS6 + GW2
4	AS4 + AS5 + BS6 + GW2
5	AS4 + AS5 + BS6 + GW2
6	AS4 + AS5 + BS6 + GW2

Site-wide Alternative 1 – No Action

This alternative consists of performing no remedial actions and maintaining a "status quo" at the site for all media. Therefore, accessible soils would remain at the current locations. Present use of buildings would continue, and groundwater would be monitored.

Existing institutional controls consist of limited site security and fencing around most contaminated accessible soil to restrict direct contact of contaminants to the public. Existing environmental monitoring would involve measuring radon, and PCOC levels in the groundwater, surface runoff, and air. The no-action alternative is retained as required by the NCP.

Site-wide Alternative 2 – Institutional Controls and Site Maintenance

This alternative consists of enforcing or adding institutional controls to restrict access to contaminated media at SLDS. Land use restrictions would be implemented to control exposure by imposing well drilling prohibitions and digging restrictions. Alternative 2 would protect human health and the environment.

Site-wide Alternative No. 3 – Consolidation and Capping

This alternative consists of excavating accessible soils above the composite criteria of 5 pCi/g in the surface, or 15 pCi/g in the subsurface for Ra-226, Th-230, Ra-228 and Th-232 as explained in Section 3.2.1.5. This alternative also includes use of the derived U-238 criteria of 50 pCi/g (based on DOE Order 5400.5 guidance) for soil at all depths. These criteria are applied after subtraction of background concentrations, and using the "Sum of Ratios" (SOR) rule. This rule applies when more than one constituent is present, and states that residual contamination following excavation must meet the criteria that the sum of the ratios of each radionuclide to its cleanup criterion must be less than 1. This results in actual radionuclide concentrations after cleanup that are much less than the individual limits, as shown in the following formulas:

$$\frac{\text{greater of Ra-226 or Th-230}}{5} + \frac{\text{greater of Ra-228 or Th-232}}{5} + \frac{\text{U-238}}{50} < 1$$

in the top 15 cm (6 in) or

$$\frac{\text{greater of Ra-226 or Th-230}}{15} + \frac{\text{greater of Ra-228 or Th-232}}{15} + \frac{\text{U-238}}{50} < 1$$

below 15 cm.

The combined criteria discussed above are referred to as composite criteria because they combine the concentration limits in 40 CFR 192 for Ra-226 and Ra-228 with the limits found in DOE Order 5400.5 for Th-230 and Th-232 and for other radionuclides found at significant concentrations.

In addition to excavation of the accessible soils, Alternative 3 includes excavation of contaminated material beneath the cap site as well. Treatment will be incorporated into this alternative if a treatment technology is demonstrated to be cost effective prior to completion of the remedial action. Overburden (ie, material below the criteria that must be removed to access the contaminated material and treatment residuals) having a sum of ratios less than 1 may be used as backfill to replace the contaminated material removed.

The cap, for costing purposes, is assumed to consist of all-natural materials (no synthetic liners or other man-made materials) and will consist of a low permeability liner beneath the consolidated materials and a low permeability clay cap above. Alternative 3 also includes decontamination and surface restoration plus decontamination, partial dismantlement, and disposal of contaminated building surfaces when the building is made available. Under this alternative, groundwater monitoring would continue and institutional controls would be implemented. Restrictions would be applied to inaccessible soils left under buildings, railroads, and other permanent structures and radon control measures would reduce the potential for human exposure until the remedy for inaccessible soils is determined. For cost estimates, it was assumed inaccessible soils would be excavated concurrently with accessible soil, but shipped to off-site disposal. Alternative 3 would be protective of human health and the environment. Alternative 3 would also be protective of groundwater as it would remove the potential source of contamination from contact with groundwater and water percolating through the fill material.

A long-term management plan would be developed to address notification requirements for property owners as well as monitoring and maintenance requirements into the future. This plan would be developed during the design phase and included in agreements with property owners. This plan would include provisions addressing how property owners should contact the federal agency responsible for long-term control of impacted areas and how these areas will be reviewed, maintained, and monitored by the Federal Government after completion of Alternative 3.

Site-wide Alternative No. 4 – Partial Excavation and Disposal

This alternative would consist of excavating accessible soils to the composite criteria in the upmost two feet. Below 2 ft, risk-based criteria developed in accordance with NRC's ALARA guidance would be used. Appendix C provides an analysis of risks and costs associated with a range of potential industrial/construction worker target removal criteria. The purpose of this analysis was to determine the optimum balance of protectiveness and cost in development of subsurface target removal criterion for radionuclides at SLDS. This analysis only addressed risk from radionuclides and did not consider chemicals or metals. The results of this ALARA analysis show that use of target removal criteria of 50 pCi/g Ra-226, 100 pCi/g Th-230, and 150 pCi/g U-238 should result in a protective remedy for the industrial/construction worker exposure scenario. As with Alternative 3, application of the SOR principle would reduce residual concentrations well below the target removal criteria for each individual radionuclide. The SOR rule would be applied using the composite criteria as described in Alternative 3 from the surface to 2 feet deep, however, below 2 feet the equation would be modified to apply the ALARA criteria described below:

$$\frac{\text{Ra-226}}{50} + \frac{\text{Th-230}}{100} + \frac{\text{U-238}}{150} < 1$$

The criteria described above will be referred to subsequently in this report as the "ALARA criteria" for clarity. As with the sum of ratios equation shown for the composite criteria, the sum of ratios equation shown above for the ALARA criteria is based on above background concentrations of each radionuclide. The ALARA criteria represent subsurface target removal criteria that would result in residual concentrations that meet the CERCLA risk criteria for worker exposures. Overburden below ALARA criteria would be used as backfill below 2 feet depth provided it does not exhibit a hazardous characteristic. Treatment will be incorporated into this alternative if a treatment technology is demonstrated to be cost effective prior to completion of the remedial action. Above 2 feet, overburden and treatment residuals would be used as backfill only if it is below the composite criteria, and is not hazardous. Approved off-site borrow would supplement backfill as needed.

Because contamination at Plant 7 is highly localized and consists almost entirely of Ra-226, soil exceeding the composite criteria would be excavated to depth in the Plant 7 footprint.

Risk-based guidelines used to address soil below two feet in depth would result in the removal of the concentrated contaminants above and below the water table. The source of soil contamination that may contribute to potential future groundwater contamination will be removed. However, because SLDS is in an area expected to remain highly industrialized, agreements will be negotiated to restrict the installation of wells within specified areas to prevent unauthorized use of groundwater.

Surface decontamination, surface restoration, and partial dismantlement will be implemented when the contaminated building is made available by the owner. All excavated soils and debris having contaminants above the ALARA criteria would be disposed off-site at an appropriate disposal facility. For inaccessible soils, institutional controls would be maintained to reduce the potential for human exposure. Inaccessible soil would be addressed when an appropriate remedy has been determined. Alternative 4 would protect human health and the environment. A long-term management program similar to that described under Alternative 3 would be instituted to ensure long term protectiveness. Changes in future site usage may result in reevaluation of protectiveness. Ongoing and future development would result in generation of excavated soils requiring disposal by the Federal Government. Costs for this collection and disposal are undefined but are anticipated to be substantial.

Site-wide Alternative No. 5 – Complete Excavation and Disposal

This alternative consists of excavating and disposing of the accessible soils above the composite criteria; surface decontamination, surface restoration, and partial dismantlement of building surfaces; and implementation of monitoring and institutional controls for groundwater and inaccessible soils. Overburden below composite criteria would be used as backfill provided it does not exhibit hazardous characteristics. Alternative 5 would be protective of human health and the environment and would meet applicable standards for levels of residual contamination. As with Alternative 4, excavation of the source material would also be protective of the groundwater. A long-term management plan as described in Alternative 3 would be implemented for areas with inaccessible soils until the remedy for inaccessible soils is determined.

Site-wide Alternative No. 6 – Selective Excavation and Disposal

This alternative focuses on reducing the need for future studies, designs, and remedial actions, in addition to protection of human health and the environment relative to Alternative 4. The depth of excavation would be extended for the most stringent (composite) criteria, thereby further reducing residual risk. To address these concerns, the depth of excavation above the composite criteria was extended to 6 ft in most areas of the plant and to 4 ft in other areas. For the purposes of preparing cost estimates, it is assumed that excavation to the most stringent criteria would proceed to a depth of 6 ft west of the St. Louis Terminal RR Association tracks and at the former locations of Buildings 116, 117, 704, 705, 706, and 707. Excavation for the composite criteria would stop at 4 ft at all other areas at SLDS including the VPs and under the roads. The columbium-tantalum processing area beneath Plant 5 would not be remediated under this alternative. The boundary of this area would be delineated prior to initiating remedial activities. Only approved off-site borrow would be used to fill in the excavations above 4 or 6 feet across SLDS and the VPs. Because only off-site borrow would be used as backfill, treatment is not a viable option for this alternative. As in Alternative 4, contamination exceeding the ALARA criteria (SOR>1 for 50 pCi/g Ra-226, 100 pCi/g Th-230, and 150 pCi/g U-238) would be excavated to whatever depth is required. Material below the ALARA criteria could be used as backfill at depths greater than the composite criteria concentration depth. Thus, below 6 ft (or 4 ft in some areas), the material exceeding the ALARA criteria would be replaced with material less than the ALARA criteria for radionuclides, provided it does not exhibit a hazardous characteristic. Hazardous characteristic tests would be conducted on samples of potential backfill from each excavation.

Inaccessible soils would not be excavated under this alternative. Institutional controls would remain in place to ensure continued protectiveness until a remedy for inaccessible soils is determined. Ongoing and future development may result in generation of excavated soils requiring disposal by the Federal Government. Costs for this collection and disposal are undefined, but are anticipated to be much less than Alternative 4 because of the low frequency of disturbance of soils deeper than 4 to 6 ft.

5. DETAILED ANALYSIS OF ALTERNATIVES

5.1 INTRODUCTION

The detailed analysis of remedial alternatives follows the development and screening of alternatives and provides the basis for identifying a preferred remedial alternative. This section analyzes and evaluates site-wide remedial alternatives retained from Section 4. The alternatives capable of addressing the contamination are evaluated in detail based on CERCLA criteria. Section 5 presents site-wide remedial alternatives and conducts a detailed analysis of alternatives using CERCLA criteria (Section 5.2), and compares these alternatives to each other (Section 5.3). The detailed and comparative analysis of the site-wide remedial alternatives includes evaluations of overall protection, compliance with ARARs, long- and short-term effectiveness, reduction in contaminant volume, toxicity or mobility due to treatment, implementability, and cost. Conclusions are presented in Section 5.4. The preferred alternative will be discussed in the Proposed Plan which will be issued concurrently with the FS.

In accordance with statutory requirements under CERCLA, remedial actions must (EPA 1988):

- be protective of human health and the environment;
- attain ARARs or provide grounds for justifying a waiver;
- be cost-effective;
- utilize permanent solutions and alternative treatment technologies to the maximum extent practicable; and,
- satisfy the preference for treatment that reduces volume, toxicity, or mobility as a principal element [40 CFR §300.430(f)(1)(c)].

Evaluation of these CERCLA requirements for SLDS will be performed, taking into full consideration the remedial unit screening results of Section 4.

In addition, these requirements emphasize long-term effectiveness and other considerations in evaluating each of the alternative remedial actions. These considerations include:

- long-term uncertainties associated with land disposal;
- persistence, toxicity, and mobility of radionuclides and other hazardous substances, and their propensity to bioaccumulate;
- long- and short-term potential for adverse health effects from human exposure;

- potential threat to human health and the environment associated with excavation, transportation, and disposal;

- long-term maintenance costs; and

- potential for future remedial action costs if the alternative remedial action being discussed were to fail [40 CFR §300.430(e)(9)].

Accordingly, retained remedial alternatives will undergo detailed comparative analysis using the following criteria:

- Threshold Criteria
  - overall protection of human health and the environment, and
  - compliance with ARARs.

- Balancing Criteria
  - long-term effectiveness and permanence;
  - reduction of volume, toxicity, and mobility through treatment;
  - short-term effectiveness;
  - implementability; and
  - cost.

- Modifying Criteria
  - state acceptance, and
  - community acceptance.

Overall protection of human health and the environment and *compliance with ARARs* are "threshold criteria" that any remedial alternative must meet before being considered for implementation. During detailed analysis of remedial alternatives, each alternative must be evaluated to determine how the alternative achieves and maintains protection of human health and the environment. Similarly, each remedial alternative must be assessed to determine how the alternative complies with ARARs, or if a waiver is required and how it is justified.

Long-term effectiveness; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost are referred to as "balancing criteria." These represent the primary selection criteria for alternatives determined to be protective of human health and the environment and to comply with ARARs.

Long-term effectiveness and permanence is an evaluation of the magnitude of residual risk (risk remaining after implementation of the alternative), and the adequacy and reliability of controls used to manage the remaining waste (untreated waste and treatment residuals) over the long term. Alternatives that afford the highest degrees of long-term effectiveness and permanence leave little or no untreated waste at the site, make long-term maintenance and monitoring unnecessary, and minimize the need for institutional controls.

Reduction of volume, toxicity, and mobility through treatment is an evaluation of the ability of the alternative to reduce the volume, toxicity, and mobility of the waste. The irreversibility of the treatment process, and the type and quantity of residuals remaining after treatment are also assessed by this criterion. Applying soil treatment to SLDS will be carried forward as a conditional part of Alternatives 3, 4, 5, and 6. If a viable and cost effective treatment technology could be identified and proven to work on SLDS soils before the completion of remediation, treatment could be reconsidered at that time.

Short-term effectiveness addresses the protection of workers and the community during the remedial action, the environmental effects of implementing the action, and the time required to achieve cleanup goals.

Implementability addresses the technical and administrative feasibility of implementing an alternative, and the availability of various services and materials required during its implementation. Technical feasibility assesses the ability to construct and operate a technology, reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the alternative. Administrative feasibility is addressed in terms of the ability to obtain approval from appropriate regulatory agencies.

Cost of an alternative reflects the capital and O&M requirements for each alternative and provides an estimate of the Fiscal Year (FY) 98 dollar cost of each alternative. The costs estimated in this report are based on quotes from suppliers, generic unit costs, vendor information, conventional cost-estimating guides, prior experience, and other information. The cost estimates are developed for FY 98 dollars, with no escalation or discount factors. The FS-level cost estimates have been prepared from the information available at the time of the estimate for guidance in project evaluation and implementation. They are believed to be accurate within a range between -30 percent and +50 percent of actual costs in accordance with EPA guidance (EPA 1988). The actual costs for these actions could be higher than estimated because of unexpected site conditions and the potential for delays in taking the action. Correspondingly, costs could be lower if construction excavation or disposal efficiencies are achieved. Appendix B presents the assumption and uncertainty details which affect the cost estimates.

Uncertainty in remedial efficiency for contaminated soils affects cost estimates. A sensitivity cost analysis presented in Appendix B describes potential cost analysis effects of variations in remedial efficiency by examining the impact of soil volume changes. Soil volume was chosen because it serves as the basis for removal, transport, disposal, and other costs. The effect of using various discount rates is evaluated also.

The *state acceptance* and *community acceptance* criteria are modifying criteria. They are not addressed in this document but, as specified by CERCLA guidance, will be addressed as part of the ROD. The preferred alternative should be acceptable to state and support agencies. Also, the concerns of the community should be considered in presenting alternatives that would be acceptable to the community. An initial discussion about possible impacts to the community are presented in each alternative. These two criteria would be evaluated following comments on the FS/PP received during the public comment period and would be addressed in the response to public comments and incorporated in the ROD for SLDS.

5.2 DETAILED ANALYSIS OF ALTERNATIVES

This section presents a detailed analysis of site-wide alternatives. This analysis describes and evaluates each alternative against the criteria outlined in Section 5.1. The site-wide alternatives are illustrated in Table 5-1. Table 5-2 provides a brief summary of the main elements of each alternative.

Table 5-1. Site-wide Alternatives for the SLDS

Site-wide Alternative	SLDS Remedial Units		
	Accessible Soils	**Buildings**	**Groundwater**
1	No action	No Action	No Action
2	Institutional controls and site maintenance	Institutional controls and site maintenance	Institutional controls and site maintenance
3	Containment (consolidation and capping)	Decontamination and surface restoration plus partial dismantlement and disposal	Same as 2
4	Excavation/disposal	Same as 3	Same as 2
5	Same as 4	Same as 3	Same as 2
6	Same as 4	Same as 3	Same as 2

Environmental monitoring and sample frequency for each of the SLDS alternatives are described below. A final detailed monitoring plan would be developed during remedial design and submitted for regulatory agency review and approval. Environmental monitoring would be tailored to the selected remedial alternative so that monitoring objectives will be realized. An adequate monitoring program considers periodic sampling of all media that would be affected by the continued presence of contaminants in environmental media. Periodic monitoring should be conducted of the air (for radon emissions and particulates), external gamma radiation, stormwater (to measure surface runoff impacts), and groundwater at representative locations.

The administrative feasibility of Alternatives 4, 5, and 6 would be impacted by the requirements for coordinating transport and disposal. Numerous federal regulations would need to be addressed, and licenses, permits, and administrative procedures would need to be in place before transport and disposal could take place. These requirements might affect the time required to implement these alternatives.

As will be discussed under the long-term effectiveness and permanence subsections for Alternatives 3, 4, 5, and 6, excavation of all contaminated accessible soils and subsequent disposal would provide immediate source control since all accessible soils that pose a health risk would be removed. Excavation of these contaminated soils would eliminate the need for long-term management, monitoring, and maintenance in the areas from which contaminated soil is removed.

Table 5-2. Summary of the Main Elements of the SLDS Alternatives

Element	Alternative 1 No Action	Alternative 2 Institutional Controls and Site Maintenance	Alternative 3 Consolidation and Capping	Alternative 4 Partial Excavation and Disposal	Alternative 5 Complete Excavation and Disposal	Alternative 6 Selective Excavation and Disposal
Monitoring of groundwater, sediments, surface water, and ambient air	Minimum of 30 years	Minimum of 30 years	Minimum of 30 years at cap site	Minimum of 30 years	May be terminated if inaccessible soils are removed in a future remedy.	Minimum of 30 years
Institutional controls	N/A	Entire site, including groundwater use	Required for inaccessible soils and groundwater at SLDS	Required for inaccessible soils and groundwater at SLDS	Required for inaccessible soils and groundwater at SLDS	Required for inaccessible soils and groundwater at SLDS
Buildings and structures radon controls	N/A	Implement	Implement until selection of remedy for inaccessible soils	Implement until selection of remedy for inaccessible soil	Implement until selection of remedy for inaccessible soil	Implement until selection of remedy for inaccessible soil
Construction of cap	N/A	N/A	Cap with low permeability cover and liner	N/A	N/A	N/A
Operation and maintenance of cap/cell area	N/A	N/A	Minimum of 30 years	N/A	N/A	N/A
Excavation and backfill of all accessible soils	N/A	N/A	Implement, return soil below composite criteria as backfill	Implement, soil <ALARA criteria used as backfill below 2 feet. Soil < composite criteria used as backfill above 2 feet.	Implement, return soil below composite criteria as backfill.	Implement, return soil below ALARA criteria to excavations below 4 (or 6 ft). Off site borrow above 4 to 6 ft.
Transportation of excavated soils above criteria	N/A	N/A	To containment cap area	To disposal site	To disposal site	To disposal site
Decontamination and partial dismantlement of buildings and structures located at SLDS, restoration of buildings, and transport of debris	N/A	N/A	Debris transported to disposal site	Debris transported to disposal site	Debris transported to disposal site	Debris transported to disposal site

5.2.1 Alternative 1 – No Action

The no-action alternative was developed to provide a baseline for comparison with other alternatives in compliance with CERCLA requirements. This alternative consists of performing no remedial actions and maintaining a "status quo" at the site. Therefore, contaminated soils would remain at their current locations; buildings and structures would continue to be used and operated as is currently being done; and routine monitoring of air, buildings, groundwater, storm water, and NESHAPs airborne emissions would occur.

5.2.1.1 Overall Protection of Human Health and the Environment

The no-action alternative is not protective of human health or the environment. As indicated by the BRA, potential current and future risks at the site could exceed the acceptable risk range. The current risks of direct contact with and ingestion and inhalation of contaminated soils would continue and could increase over time if current access control measures are not maintained. Existing buildings, structures, and paved surfaces which deter human access to underlying soils could also undergo eventual deterioration, thereby increasing the potential for human exposure to site-related contamination. The potential for human exposure to contaminants and the potential for offsite migration could increase over time as a result of disturbances by humans and natural processes. Under the no-action alternative, SLDS would continue to pose potentially unacceptable risks under future-use scenarios.

Current risks associated with exposure to contaminated groundwater are minimal since water bearing strata at SLDS are not sources of drinking water. However, use of SLDS groundwater without treatment could pose potentially unacceptable risks to human health from both naturally occurring constituents and those introduced by humans under future risk scenarios if it is used for human consumption. Because the no-action alternative contains no provision to restrict groundwater use, Alternative 1 is not protective of human health.

5.2.1.2 Compliance with ARARs

Alternative 1 does not comply with ARARs. The residual radionuclide concentrations in soil and on building surfaces would continue to exceed guidelines. Groundwater use restrictions would not be implemented at SLAPS and SLDS.

5.2.1.3 Long-Term Effectiveness and Permanence

All potential future risks, which are summarized in Section 2.5.4 and discussed in detail in the BRA, remain at levels which exceed the 10^{-6} to 10^{-4} risk range because none of the contaminated media would be removed. Although existing site security would provide limited control over exposure to site contaminants, this alternative would provide no additional controls to prevent exposure to contaminants. Furthermore, site security would not be a required component of this alternative. Uncontrolled migration of contaminants from the source area may occur via uptake by biota, leaching into groundwater, radon gas emissions, and surface erosion and runoff. Under plausible future land-use scenarios, there are potential unacceptable risks to human health and the environment because the contaminated soils would remain.

Under Alternative 1, contamination on building surfaces and in groundwater would remain. Because this contamination is not treated, contained, or controlled, potentially unacceptable risks may exist under future risk scenarios. The concentration of radiological contaminants in groundwater would not significantly decrease in the near future since no remedial actions would be taken. Groundwater flow at SLDS is toward the Mississippi River with an estimated discharge from the site of 4,500 L/d; dilution effects of the Mississippi River are substantial. Consequently, the potential for human exposure under future risk scenarios is low because the groundwater is not used as a source of drinking water, is neither suitable for nor likely to become a source of drinking water, and has little potential for offsite migration.

Pursuant to the Superfund Amendments and Reauthorization Act (SARA), a site review would be conducted every five years because radioactive contaminants would remain onsite above health-based levels following the implementation of this alternative. While more frequent monitoring would be performed, the five-year reviews provide for a more extensive evaluation of data obtained from ongoing monitoring and provide information on the presence and behavior of contaminants in soils, sediments, groundwater, and air.

For the purpose of this FS, it is assumed that the current environmental monitoring program would continue for 30 years. However, the actual length of the monitoring program would be based on the results of five-year reviews and may be in perpetuity.

5.2.1.4 Reduction of Contaminant Volume, Toxicity, or Mobility through Treatment

No reduction in contaminant volume, toxicity, or mobility through treatment is achieved under the no-action alternative since no treatment process is proposed under this alternative.

5.2.1.5 Short-Term Effectiveness and Environmental Impacts

Effects on Community and Workers

There are no significant short-term risks associated with the no-action alternative beyond baseline conditions. There would be no additional short-term health risks to the community because no remedial actions would be implemented. Under current site usage, workers would not be exposed to any additional health risks. As summarized in Section 2.5.3 and discussed in detail in the BRA, the risk levels for most current receptor conditions are in or below the 10^{-6} to 10^{-4} range; however, unacceptable current risks were projected by the BRA for a construction worker digging in contaminated soils.

Geology and Soils. The no-action alternative is the baseline case and may have an adverse effect on geology due to potential degradation of soils by way of uncontrolled contaminant migration. All accessible soils and inaccessible soils would remain in place.

Water Quality. Under the no-action alternative baseline case, it is anticipated that degradation of the upper hydrostratigraphic unit at SLDS may occur. However, this would have little impact upon available water quality since the unit is not a drinking water source and is of very low level. There is little evidence to suggest that it ever will be a drinking water source considering the abundant availability of surface water resources (ie, Mississippi River).

Under the no-action alternative, any discharge of groundwater to the Mississippi River would continue. Groundwater discharging to the Mississippi River from SLDS would not substantially affect water quality in the river due to the dilution afforded by the 5×10^6 m^3/s (177,000 cfs) river flow.

Biotic Resources. At SLDS, contaminant transport to the Mississippi River would continue under the no-action alternative. However, due to the large flow rate and volume of the Mississippi River, contaminants entering the river would have little, if any, effect upon the aquatic community. No commercially or aesthetically valued biotic resources exist onsite.

Threatened and Endangered Species. No threatened, endangered, or candidate species or their habitats have been observed on the site. As discussed previously, the state- and federal-endangered pallid sturgeon could be present in the Mississippi River in the vicinity of the site. Even so, the effects of contaminants would be minimal due to the large dilution volume afforded by the river. Therefore, no effects on this species are expected under the no-action alternative.

Wetlands Impacts. No designated wetlands occur near the SLDS.

Floodplains Impacts. Floodplains may be affected under the no-action alternative baseline case, to the extent that erosion and flooding may result in redistribution of contaminated media.

Air Quality. There would be effects on air quality to the extent that wind erosion could result in contaminated soil becoming airborne and the release of radon would continue.

Archaeological, Historical, and Cultural Resources

Under the baseline case, there would be no effects on archaeological, historical, or cultural resources at SLDS.

Land Use and Recreational/Aesthetic Resources

Current land use at the SLDS would continue, but future development of the properties would be limited due to the presence of contaminated soil.

Socioeconomic and Institutional Issues

Community and Institutional Issues. Mallinckrodt Inc. is generally supportive of remedial activities, however, management expresses concern over disruption of plant operations during implementation. The community has developed a bike trail on a portion of the City Property. In a

1996 interim action, 750 yd^3 of contaminated soil was excavated from the City Property to reclaim the land for recreational use in response to this community project.

Public Services. The no-action alternative would place no additional demand on public utilities or services. The no-action alternative could lead to a situation requiring emergency response actions if public access to and use of the site are not strictly controlled. However, assuming a continuation of existing conditions and no soil-disturbing activities, the levels of radioactive contamination do not pose any acute health risk to either onsite workers or the general public. Therefore, minimal impact on emergency services would be expected.

Transportation Impacts. There would be no additional transportation effects above baseline conditions under the no-action alternative.

Unavoidable Adverse Impacts and Mitigative Measures

The unavoidable adverse impacts of the no-action alternative are the potential risk to human health and the environment posed by site related contamination.

Short-Term Uses and Long-Term Productivity

Under this alternative, short-term use and long-term productivity would remain the same and land use would be restricted.

Cumulative Impacts

There are no cumulative impacts anticipated to SLDS from the No Action Alternative.

5.2.1.6 Implementability

Alternative 1 can be easily implemented. Long-term monitoring and five-year evaluations of site remedy effectiveness can be easily implemented. The long-term environmental monitoring program would be a continuation of the current routine monitoring at SLDS.

5.2.1.7 Cost

Under this alternative, there are no capital costs. The current environmental monitoring program would continue for 30 years at an estimated cost of $22 million. Supporting information on costs is provided in Appendix B.

5.2.2 Alternative 2 – Institutional Controls and Site Maintenance

Under this alternative, institutional controls and site maintenance would be implemented to prevent access to contaminated areas. The institutional controls would include use limitations through deed restrictions, land use restrictions through zoning, and groundwater use restrictions through groundwater use advisories or well-drilling permits, as described below. Site maintenance would include surveillance of land, restricted groundwater use, environmental monitoring of affected media, and implementing minimal engineering controls such as radon abatement. Site security, including fences and signs, is already maintained at most of the downtown areas, including 24-hour security at the Mallinckrodt Inc. Plant.

Requests for rezoning of affected properties to restrict their future use is possible under local zoning laws. Under zoning law, however, changes operate prospectively; uses which existed on the property previously cannot be changed without court action. Non-conforming uses (eg, pre-existing uses that would not be allowed under the terms of the new zoning ordinances) are allowed to continue as long as the use is not terminated or abandoned by the property owner, or as long as the use is substantially modified to increase the degree of non-conformity. Generally, a cessation of the use for a period of about two years is considered an abandonment of the non-conforming use, and it would no longer be enforceable.

USACE would take appropriate legal actions to impose restrictions necessary to protect human health and the environment. It is anticipated that the cooperation of the current owners can be enlisted.

Well-drilling prohibitions and well-use advisories can reduce the risks of exposure to contaminated groundwater. Restrictions on future use of groundwater could be incorporated via land use restrictions.

The objective of environmental monitoring is to measure contaminant concentrations, location, and movement. Monitoring would include sampling all environmental media in order to measure the levels of gamma radiation and radon gas in the soils beneath buildings and structures, the levels of contaminants in the buildings and structures themselves, and the levels in groundwater.

If radon levels exceeding 40 CFR 192 are detected by monitoring, the neither passive or active radon controls could be implemented to reduce exposure inside buildings. A passive collection system (trench vent) could be installed around buildings to reduce radon migration from underlying soils. Trench vents are constructed by excavating a narrow trench to the footings around the foundation and backfilling with gravel. The low resistance provided by the gravel would provide radon gas a preferential path outside of the buildings. Vertical pipes could be installed in the trenches to collect the gas. A long-term monitoring plan would have to be developed to measure the effectiveness of passive collection systems. Active collection systems use negative pressure to vent radon gas released into the building. These systems are most effective for reducing radon concentrations inside buildings by drawing outside air into the buildings, thus reducing radon concentrations to acceptable levels, but increasing the costs of heating and cooling the buildings. The final decision on which radon mitigating measures are implemented would be made during the design phase.

5.2.2.1 Overall Protection of Human Health and the Environment

Alternative 2, institutional controls, is protective of human health and the environment. The risk of exposure to site-related contamination would be reduced to levels acceptable under current use and probable future use scenarios. However, institutional controls are not reliable in the very long term.

This alternative is protective of human health since institutional controls would limit site access, thereby reducing potential for future exposure. Risks will be low as long as access to contaminated material is controlled. Under Alternative 2, institutional controls would be implemented that would restrict and regulate access to contaminated soils. Fences and site security currently restricting access to SLDS would be maintained and improved as conditions warrant. Contaminated portions of the vicinity properties would be fenced and signs would be posted.

Precautionary measures would be required for onsite workers. Workers' exposure would be controlled through strict adherence to a site health and safety plan, training, medical surveillance, and environmental monitoring.

Occupancy and use of contaminated buildings would be restricted under Alternative 2 to limit worker exposure to acceptable levels. Additionally, radon control measures would be implemented at SLDS buildings where radon gas is a concern. Radon exposures would be limited by installing passive or active radon controls in affected buildings at SLDS.

Precautionary measures, such as land use restrictions, would be implemented to prevent unauthorized use of site groundwater for any reason.

Under this alternative, means to control access to groundwater at locations where contaminants may migrate offsite would be maintained. Because this alternative offers the option of implementing institutional controls, it is more protective than the no-action alternative.

5.2.2.2 Compliance with ARARs

In order to meet the ARARs for radioactive contaminants in soil, groundwater, air, and buildings, implementation of institutional controls would be required. Without institutional controls, ARARs would not be achieved under this alternative. That is, the remediation would not be in compliance for any location where accessible soil is left uncontrolled and where 40 CFR 92 is determined to be an ARAR. However, with appropriate institutional controls acceptable risk levels can be achieved for the contaminated soil left in place. It would be possible under 40 CFR 192 to release property that is above authorization limits without radiological restrictions, if supplemental limits have been invoked. Institutional controls to restrict access would limit public exposure to contaminated soils, buildings, and groundwater within the limits of applicable guidelines.

Present day land use activities would be continued at SLDS for Alternative 2. The BRA (ANL 1993) radiological exposure scenarios assessed risks above the EPA 10^{-6} to 10^{-4} risk range for construction workers at Mallinckrodt Inc. Section 2.4 discusses these current user scenarios, which assume that protective measures, such as institutional controls in Alternative 2, do not exist. The BRA total risk results show that these current user scenario risks are 5.2×10^{-3} for the

Mallinckrodt Inc. construction worker (ANL 1993). The key environmental release mechanisms and transport pathways considered important for these current receptors are:

- external gamma exposure,
- radon gas release, and
- particulate emissions.

The external gamma irradiation pathway in general contributes the highest percentage of the risk.

The groundwater pathway is not a viable environmental release mechanism because the upper hydrostratigraphic unit has poor quality water, is a low yield system, and will be controlled through use restrictions. Furthermore, groundwater contamination is naturally attenuated to low levels upon reaching surface water. Since the BRA was conducted, several actions have been undertaken at SLDS that would have reduced the risk from that reported in the BRA. Contaminated soil near the surface has been excavated from the levee and Plant 10, and most of the buildings in which MED/AEC activities were conducted have been demolished.

In employee scenarios, these exposure pathways would be maintained at safe levels through continued compliance with worker safety regulations. The accessibility of the sites to recreational users and trespassers would be controlled through the use of fences, appropriate sign posting, and access controls. Institutional control negotiations with the property owners would be the mechanism used to put in place the requirements needed to maintain these measures.

5.2.2.3 Long-Term Effectiveness and Permanence

This alternative would be effective in protecting human health as long as the institutional controls can be implemented. Current security measures limit access to the most contaminated areas. Additional limitations such as new fencing, security personnel, and land use restrictions would reduce the potential for public exposure under future use scenarios. Even though groundwater is not used and is not expected to be used in the future for drinking (due to the abundance of surface water and poor groundwater quality), restrictions would further preclude such use.

Institutional controls such as security measures and land-use restrictions would only be reliable on USACE property or on property in which USACE negotiated agreements with the owners or affected municipalities. Unless such an arrangement can be made, long-term protection against future exposure cannot be ensured under this alternative.

Radioactive contaminants would remain onsite at levels exceeding guidelines for release without radiological restrictions following the implementation of this alternative; thus a review of remedy effectiveness would be conducted every five years, to evaluate the need for further remedial action. Environmental monitoring would be conducted to measure the nature and extent of contamination.

Irreversible and Irretrievable Commitment of Resources

The only irreversible or irretrievable commitment of resources under the institutional controls and site maintenance alternative would be land use that would be confined to current uses.

5.2.2.4 Reduction of Contaminant Volume, Toxicity, or Mobility through Treatment

No reduction in contaminant volume, toxicity, or mobility of contamination through treatment would be achieved under this alternative since no treatment process is proposed.

5.2.2.5 Short-Term Effectiveness and Environmental Impacts

Effects on Community and Workers

Implementation of this alternative would result in no significant increase in risk to either the community or onsite workers. There would be no significant short-term risks to the community beyond baseline conditions. Strict adherence to an approved health and safety plan and continuous monitoring for airborne contamination would keep the risk levels for workers within the acceptable ranges. The control of recreational and trespasser access to contaminated areas will lower the risk level to acceptable levels by reducing the exposure duration.

Environmental Impacts

Because no contamination is removed under site-wide Alternative 2, the effects on the environment are the same as those described for the no-action alternative in Section 5.2.1.5.

Archaeological, Historical, and Cultural Resources

There would be no effects on archaeological, historical, or cultural resources at SLDS.

Land Use and Recreational/Aesthetic Resources

Implementing institutional controls such as deed restrictions would not change the current use of affected areas at SLDS. Alternative 2 would restrict future development of the sites due to the presence of contaminated soil.

Socioeconomic and Institutional Issues

Community and Institutional Issues. Community issues and concerns would be the same as those found under Alternative 1, the no-action alternative.

Public Services. Alternative 2, like the no-action alternative, would place no additional demand on public utilities or services.

Transportation Impacts. There would be no additional transportation effects above baseline conditions under Alternative 2.

Unavoidable Adverse Impacts and Mitigative Measures

Community issues would be mitigated by a well-planned public information and community relations program to ensure that community members, property owners, and local officials are well-informed about the various steps in the implementation of the alternative and progress being made toward completion of the action. Coordination and formal agreements with local officials may be necessary to mitigate institutional impacts associated with restrictions on land uses.

Short-Term Uses and Long-Term Productivity

Under this alternative, short-term use and long-term productivity would remain the same. Land use would be restricted in accordance with institutional controls.

Cumulative Impacts

The same cumulative impacts as those presented for Alternative 1 would apply to this alternative.

5.2.2.6 Implementability

Implementation of this alternative could take place within one year; however, some difficulties may arise in establishing institutional controls. Deed restrictions or rezoning may require purchase of SLDS properties or negotiating agreements with the local municipalities.

Securing agreements with the property owners to modify the deed could be difficult. USACE could negotiate with the St. Louis city government to exercise eminent domain and condemn the properties for the purpose of protecting human health and the environment. However, since the current risk does not pose a significant threat to human health, this type of action may not be warranted. Condemnation by eminent domain requires a demonstration that no other reasonable alternative exists. If successful, subsequent condemnation proceedings would be required to establish a fair market value for the property.

It would be possible to impose land-use restrictions by way of local zoning authorities. These zoning changes can affect only future, not present, uses. Rights to current uses are "grandfathered" and are not surrendered until the use has been voluntarily discontinued or abandoned for a period of generally two years. Rezoning, which adversely affects the economic value of a private holding, might entitle the owner to compensation. Environmental monitoring of media would be readily accomplished.

5.2.2.7 Cost

The cost to implement the Alternative 2 remedial action is $29 million (Appendix B). These costs include site maintenance on fences and facilities plus institution of deed restrictions. Deed restrictions would need to be negotiated with property owners, with legal fees depending on the length of the negotiations. The cost of not implementing any remedial action per Alternative 1 is $22 million (Appendix B). The difference in cost between Alternative 2 and Alternative 1 is $7 million.

Long-term environmental monitoring constitutes the difference between Alternative 1 and Alternative 2. Maintenance of institutional controls are essentially the same in the two alternatives because institutional controls are already in place at most of the SLDS locations. The environmental monitoring program would involve sampling of air, groundwater, surface water, and stormwaters. Supporting information on the costs is provided in Appendix B.

5.2.3 Alternative 3 – Consolidation and Capping

This alternative consists of excavating soil exceeding the composite criteria from SLDS. The resultant soils and waste would be consolidated and capped at a suitable downtown location. This property would be acquired by USACE who would build and maintain the cap. Either the city property or the area formerly occupied by the 50 series buildings at Plant 2 could be utilized. Estimated volumes are presented for cost estimating purposes only. Building 25 would be decontaminated or dismantled when the owner makes it available. For costing purposes, it was assumed the cap would consist of all-natural materials (no synthetic liners or other man-made materials).

Contaminated soil beneath the cap site would remain in place under the cap, but it may have to be conditioned in some fashion to support the consolidated soil load. The potential for subsidence over the proposed area to be capped would be evaluated during remedial design. Remedies to prevent uncontrolled subsidence would be employed as required to stabilize the cap area. For example, dynamic compaction and sheepsfoot roller techniques could be used to address subsidence (BNI 1994). These costs are included in the Alternative 3 cost analysis.

Contaminated soils at the vicinity properties include McKinley Iron Company, Thomas and Proetz Lumber Company, PVO Foods, the railroad properties, and the city-owned property. These soils would be excavated and transported to the capping area for consolidation and capping.

Building 25 at SLDS would be decontaminated using a combination of physical and chemical techniques as described in Section 3.4.5. That is, building 25 would be decontaminated to remove residual radioactivity exceeding applicable guidelines. Dismantlement would be performed, where necessary, if decontamination is not effective. Waste streams generated from decontamination would be collected and treated to remove radionuclide contaminants. After decontamination is complete, the buildings would be released for unrestricted use. Engineering controls for radon would be implemented in Building 101 until the owner made the soil available for excavation. Costs are estimated based on the assumption that the soil becomes accessible during the remedial action period. Worker protection standards would follow OSHA regulations for radon control.

Sediment from manholes, catch basins, and sewers at SLDS would be removed by standard excavation techniques. Excavation and removal of the sediment, and sewer and drain lines where necessary, would involve tracing lines through a variety of standard techniques (ie, dyes, smoke, radio transmitters). Manual use of smaller equipment such as shovels would be used around utility lines, including sewers and drains, to remove contaminated soil. Standard techniques and procedures for removal of sewer and drain lines would be performed using typical radiological precautions.

To reduce the potential for exposure and human intrusion, institutional controls would be implemented to control access to the capped area and inaccessible soils until a remedy for inaccessible soils is selected. Groundwater would be monitored but not remediated under this alternative. Groundwater use would be restricted through the use of institutional controls. Agreements would be negotiated to restrict the installation of wells within a specified area to prevent unauthorized use of groundwater. Monitoring would involve sampling to ensure that the remediation was adequate to protect human health and the environment as determined by risk assessment.

The major material-handling activities conducted while implementing this alternative would be excavation of the soils and transport of these soils to the containment area for consolidation and capping. Because this disposal alternative involves straightforward site engineering and development, the remediation can be implemented in a timely fashion.

5.2.3.1 Overall Protection of Human Health and the Environment

Alternative 3, consolidation and capping, is protective of human health and the environment. The risk of exposure to site-related contamination would be reduced to levels acceptable under current use and probable future use scenarios.

This alternative provides increased protection of human health and the environment over baseline conditions for the contaminated soils through long-term effectiveness and permanence. Under Alternative 3, soils and sediments posing potentially unacceptable risks to human health and the environment would be excavated, consolidated at a central location, and capped. Groundwater would also be protected as a result of removal of potential sources of contamination.

Residual radioactive contamination would be removed from Building 25 by means of decontamination and partial dismantlement once the building is made available by the owner. Institutional controls would limit exposure until then. Decontamination and partial dismantlement of contaminated building surfaces would effectively and permanently reduce long-term risks from radioactive contamination in building 25. Risk from radon in the buildings would be reduced by excavation of the soil around and under the buildings when the inaccessible soils become available. Radon controls will be maintained in the interim.

Under Alternative 3, the community and workers would experience minimal adverse effects. Short-term effects on the community would occur during excavation of contaminated soils; transportation of soils, sediments, and debris from dismantlement of buildings; and disposal activities. Air quality would be affected by releases of particulates and radon gas into the atmosphere during excavation of soils. The release of contaminants during excavation involves many variables, such as the surface area exposed, degree of soil agitation or movement, radionuclide concentration, rate of air movement, temperature, and humidity. All remedial activities will be controlled to keep the dose to the public below the upper public dose limit of 100 mrem/yr and down to levels that are as low as is reasonably achievable during remedial actions, and below 25 mrem/yr following remediation.

Under Alternative 3, remedial workers may experience increased exposure to site-related contamination, particularly airborne particulates, radon gas, and external gamma radiation. Based on no measures to reduce exposure, the dose to the remedial worker is estimated to be 1,147 mrem increasing the lifetime cancer risk of the maximally exposed remedial worker by 7.3×10^{-3}. Strict adherence to OSHA regulations, site health and safety plans, and site construction plans (ie, dust control plan, decontamination plan, erosion control plan) would minimize the potential for remedial worker exposure to site-related contamination. The radiological exposure of workers will be kept down to levels that are as low as is reasonably achievable. Non-radiological occupational hazards associated with Alternative 3 would be similar to those encountered in any large construction project and could result in a risk of fatality of approximately 0.006.

Radiological and non-radiological exposure risks associated with waste transport requirements for Alternative 3 are lower than that of the transportation requirements for an offsite disposal facility.

The cap system reduces the potential for human exposure, for migration of contaminants into surface water and groundwater, and for generation of fugitive dust. Capping is an effective means of preventing human exposure to underlying contaminated materials. The cap would effectively reduce the migration of contaminants by reducing water infiltration into contaminated soil. Preventing water infiltration prevents leaching of contaminants from soil into the groundwater.

Under Alternative 3, compliance with ARARs would be achieved through institutional controls that would be implemented to restrict and regulate access to capped soils. Fences and site security currently restricting access to the containment area would be maintained and improved as conditions warrant. Long-term site maintenance of the capped area, including deed restrictions, would be required to maintain protection. The cap would be periodically inspected and maintained to ensure cap integrity. Institutional controls would be used to control the access and removal of soil deeply buried under railroads and structures until a remedy is selected for inaccessible soils.

Precautionary measures would be implemented to provide compliance with ARARs through institutional controls that would prevent unauthorized use of site groundwater for any reason at sites where contaminated soil remained in place. Groundwater monitoring would be used to assess the effectiveness of the cap to reduce infiltration and leaching of contaminants to groundwater.

Groundwater monitoring and institutional controls would cease in areas where the source term was remediated and protection of human health and the environment is demonstrated by risk assessment.

5.2.3.2 Compliance with ARARs

ARARs would be achieved for Alternative 3. The relevant and appropriate sections of 40 CFR 192 would be followed for cleanup guidelines. Design requirement criteria described in 40 CFR 192 would be ARARs. Transportation requirements in 49 CFR 171 cover offsite activities and are therefore outside the scope of CERCLA.

This alternative would meet guidelines for residual soil contamination because no accessible soils with concentrations above the guideline would be released for unrestricted use. Because the groundwater beneath SLDS is of poor quality, there is minimal concern for its being used as a future drinking water source. Therefore, groundwater ARARs would be met with access restrictions. The use of institutional controls to restrict access would prevent exposures to the general public.

As a result of implementing Alternative 3, the relevant radiological exposure scenarios (ie, above the EPA 10^{-6} to 10^{-4} risk range) would be mitigated as a result of building decontamination, soil excavation, and consolidation and capping for both current and plausible future uses. The groundwater pathway is not considered a significant viable environmental release mechanism since the upper hydrostratigraphic unit has poor quality water, is a low yield system, and will be controlled through use restrictions. Furthermore, groundwater contamination is naturally attenuated to low contaminant levels upon reaching surface water.

Remedial actions under this alternative would meet applicable criteria for limits on public exposure to radioactive contaminants. Wastes transported offsite would meet the requirements of the Department of Transportation regarding packaging, labeling, and placarding.

5.2.3.3 Long-Term Effectiveness and Permanence

The active consolidate-and-cap phase of Alternative 3 will result in removal and disposal of readily accessible soil above guidelines and eventual removal of all inaccessible soils. This alternative is permanent because materials that pose a risk to health and groundwater would be removed and placed in permanent disposal. Therefore, no long-term management of soils or buildings would be required. Monitoring efforts would continue until all soils contaminated above guidelines and building debris are removed from existing locations.

As a result of meeting the guideline criteria by removing soil exceeding the guidelines, the residual risk for these properties will fall within the EPA 10^{-6} to 10^{-4} range. Capping combined with institutional controls of land use and groundwater in the capped area would be effective. Capping of the contaminated soils would effectively control exposure pathways. Regular site maintenance would be required to ensure cap integrity. Human activities, such as digging and construction onsite which could breach the cap, would be prevented by controlling site access. Similarly, natural forces such as wind, rain, burrowing animals, and vegetative roots could violate cap integrity. Consequently, long-term monitoring, control, and maintenance would be required for this alternative. A final detailed monitoring plan would be developed during remedial design and submitted for regulatory agency review and approval. In addition, a review would be conducted at least every five years to evaluate remedy effectiveness because contaminants that could potentially threaten human health and the environment would remain onsite.

Decontamination and dismantlement of Building 25 would provide long-term effectiveness in controlling human exposure because residual surface contamination would be removed.

Irreversible and Irretrievable Commitment of Resources

Resources that would be irreversibly and irretrievably committed would include materials that could not be reused and energy (eg, gasoline and diesel fuel) consumed during remedial actions. A source of approved borrow material would be required to backfill excavated areas. A clay source for the cap would be required for capping. The 2 ha (5 acres) would also be restricted from future use in order to protect the cap. Perpetual care will be taken of the committed land because the waste would retain its low level radioactivity for thousands of years. For example, the cap will be visually inspected, groundwater will be monitored, and the effectiveness of the overall system will be reviewed at least every five years.

Consumptive use of geological resources (eg, quarried rock, sand, and gravel) and petroleum products (eg, diesel fuel and gasoline) would be required for the removal construction and disposal activities of all the action alternatives. Adequate supplies of these materials are readily available in the St. Louis area.

5.2.3.4 Reduction of Contaminant Volume, Toxicity, or Mobility through Treatment

No reduction of volume, toxicity, or mobility of contaminants through treatment is anticipated under this alternative, although treatment will be retained as a conditional part of the remedy. If a treatment technology can be demonstrated to be cost effective and if regulatory approval can be obtained, then treatment can be readily added to this alternative as an adjunct to excavation.

5.2.3.5 Short-Term Effectiveness and Environmental Impacts

Effects on Community and Workers

Under Alternative 3, the community and workers would experience minimal adverse effects. Short-term effects on the community would occur during excavation of contaminated soils; transportation of soils and debris from dismantlement of buildings; and disposal activities. Air quality would be affected by releases of particulates and radon gas into the atmosphere during excavation of soils. The volume released depends on many variables, such as the surface area exposed, degree of soil agitation or movement, radionuclide concentration, rate of air movement, temperature, and humidity. Air quality conditions will be maintained within permissible limits.

Under Alternative 3, remedial workers may experience increased exposure to site-related contamination, particularly airborne particulates, radon gas, and external gamma radiation. Occupational radiation exposure is controlled by USACE through adherence to Army Regulation No. 385-1-80. In addition, OSHA regulations, site health and safety plans, and site construction plans (ie, dust control plan, decontamination plan, erosion control plan) would minimize any potential for remedial worker exposure to site-related contamination. During building decontamination, there would be short-term effects from generation of fugitive dust and exposure to liquid waste streams. These effects are expected to be controlled with proper mitigative measures such as temporary enclosures and personal protective clothing. Site health and safety officers would be present onsite to conduct health and safety training, enforce the site health and safety plan, document any site-related accidents, and to record worker exposure to site-related contamination as determined by personnel thermal luminescent dosimeters. During building decontamination, exposure to contaminated liquid waste streams may also occur. With the above approach, occupational exposure to site-related contamination would be maintained within permissible limits.

Temporary increases in site-related radon gas concentrations could also be experienced; however, the potential impact to the community would be minimal because of the rapid dispersal of radon into the atmosphere. In addition, routine monitoring of average plant boundary radon concentrations would be used to determine how operations should be modified if necessary. Decontamination of equipment, vehicles, and remedial workers before leaving the site would prevent the spread of radioactive contamination from the site. Physical containment barriers (ie, berms, dikes, ditches, etc.) would be constructed around excavation areas to prevent potentially contaminated runoff from migrating offsite.

Non-radiological occupational hazards associated with Alternative 3 would be similar to those encountered at any large construction project involving heavy excavating and hauling equipment. The injuries and fatalities are based on NUREG/CR-1266 statistics. For construction workers, the occupational risk of fatality is 4.2×10^{-8} fatalities/man-hour. It is calculated that the risk of a fatality is 0.0055. Worker/employee exposure pathways for radiological risks would be maintained at safe levels through continued compliance with worker safety regulations. The estimated number of traffic accident related fatalities to the public are predicted to be 0.067.

Environmental Impacts

Geology and Soils. Under this alternative, 81,000 m^3 (105,000 yd^3) of soil would be excavated from SLDS (assumes 20% over excavation, ie, soil below criteria inadvertently excavated because of its proximity to the contaminated soil). Of this, approximately 5,900 m^3 (7700 yd^3) would be removed from the city property and 4,000 m^3 (5,500 yd^3) would be removed from other vicinity properties.

Excavated accessible soils would be transported to a central location to be consolidated and capped. A temporary cover above the consolidated soil would be used to control wind dispersion and to address subsidence and would be incorporated in the final cap. Emplacement of the cap would reduce infiltration of precipitation, thus reducing the rate of leaching into groundwater. The excavated areas would be backfilled, revegetated or paved, and recontoured to control surface water runoff. Borrow material needed for backfill would be obtained from offsite sources and procured as a commodity in accordance with government procurement regulations in effect at the time of remedial action. Potential borrow material sources that can meet USACE's expected demands can be found in the St. Louis area. Some ecological impacts may be experienced at the borrow site location to inhabitants of the ecosystem. Approved fill in the way of low permeability clay borrow will be needed for the cap construction.

The site is underlain by hydrogeological features that do not meet the criteria for a location of a disposal facility for radioactive wastes. Physical, geological, and hydrological aspects of the site that do not meet criteria for disposal include the flood plain setting, the absence of a continuous and relatively thick confining layer, and the presence of limestone that may be karstic in nature.

Water Quality/Resources. Alternative 3 remedial design would have to address any short-term negative effect on surface water quality due to increased concentrations of radiological or chemical contaminants in runoff during earth-moving activities. The use of proper engineering controls would minimize this effect. The removal of contaminated soils would eliminate the surface water contamination from fugitive dust and surface water runoff. Treatment of groundwater from dewatering of extracted soil for discharge will serve to help alleviate the localized groundwater contamination conditions.

The proposed environmental monitoring plan would be conducted to monitor inaccessible soil left in place and to monitor the capped area.

Biotic Resources. Short-term effects during soil excavation would produce a slightly negative effect until the affected areas could be revegetated or paved. Limited terrestrial resources are present at the downtown site. Less than 2 ha (5 acres) of vegetation are present at SLDS. As described in Section 2.2.5.1, this vegetation is dominated by herbaceous species adapted to disturbance (eg, covered with gravel for vehicle parking, mowing). These species are primarily annuals except on and near the flood control levee, which is populated by introduced perennial species. This plant community would be lost during excavation, but reseeding with native herbaceous species would replace this vegetation.

Animals inhabiting the SLDS area would be directly and indirectly affected by soil excavation activities. Direct loss would occur due to displacement or mortality of affected animals present on the site. Indirect effects would include loss of perch sites and reduced food supply (eg, seeds and vegetation, insects). Excavation would have little or no effect on the activities of bird species that have adapted to human activities. Long-term negative effects would be minimal because limited suitable habitats are affected. Foods and habitat provided by herbaceous plant species would be replaced by reseeding the area after excavation.

Excavation would increase sediment loading of the Mississippi River until soil surfaces are restabilized. Continued discharge of groundwater would have minimal effect on the Mississippi River aquatic biota. Aquatic species in the river are not expected to be affected by residual contamination because of the large dilution volume in the river.

Threatened and Endangered Species. Alternative 3 would not affect protected species. No threatened, endangered, or candidate species or their habitats have been observed at SLDS. Alternative 3 would produce slight sediment loading of the Mississippi River, but have minimal effect on the pallid sturgeon. Discharge of contaminated groundwater would continue to occur, but any contaminants reaching the river would be diluted to a level that would not negatively affect the pallid sturgeon or its habitat.

Wetlands Impacts. Placing the cap would not directly disturb any wetlands.

Floodplains Impacts. Under Alternative 3, remedial actions will be taken within the boundary of the 100-year floodplain (although the floodplain is protected by the levee). A Notice of Floodplain/Wetland Involvement would be published in the Federal Register as soon as practicable after determining that a floodplain/wetland may be affected. Remedial activities proposed under Alternative 3 that would occur within the floodplain include the excavation and removal of contaminated soil on city property along the Mississippi River and/or the consolidation of contaminated soil and construction of a cap on city property.

Proposed remedial activities under Alternative 3 would be conducted so that floodplain cuts and fills would not result in an increase in floodplain elevation or increased risk of flooding. Existing floodplain boundaries that extend into proposed capping areas would be filled in (floodplain fill) so that the capped area would lie above the 100-year floodplain. Select areas outside the proposed cap area would be excavated (floodplain cut) to offset the filled floodplain volume, resulting in a net zero loss of floodplain, no increased risk of flooding, and no increase in floodplain elevation.

Air Quality. The effect of this alternative on air quality is a short-term increase in fugitive dust during excavation of the contaminated soils, transport of the soil to the consolidation area, and construction of the cap. Additionally, decontamination of Building 25 and/or dismantlement of interiors would have a potentially negative effect on the indoor air quality. Dust control methods such as wetting would be used to mitigate these effects.

Archaeological, Historical, and Cultural Resources

The interior of Building 25 at SLDS would be altered by decontamination. This building is not significant under the requirements of the *National Historic Preservation Act* and 36 CFR 60.4 (Section 2.2.9.1). Because excavations of soils at the city property would extend below overlying fill material to depths up to 4 m (13 ft), and because the property is near a destroyed Indian mound complex, there is a potential (although considered unlikely because of the long standing industrial use of the area) for encountering archaeological materials and cultural items of Native American significance during construction.

If archaeologic or historic resources are found, then the Section 106 process of the *National Historic Preservation Act of 1966* would be initiated and the resources would be evaluated as to their eligibility for listing on the National Register of Historic Places. If human remains are discovered, procedures for identifying, analyzing, and repatriating human remains consistent with the procedures of the Missouri SHPO and the State of Missouri's *Unmarked Human Burial Sites* law would be followed. If Native American burials are discovered, then consultation with Native American groups would be implemented. Implementation of these procedures will mitigate adverse impacts to human burials and their associated remains, which are the primary resources of ethnic importance to Native Americans in Missouri.

Land Use and Recreational/Aesthetic Resources

Disposal of contaminated soil would restrict future use of the capped area. In effect, the land could not be put to productive purposes other than preventing exposure to the contaminated soil disposed there.

Limited offsite land use effects would result from the purchase, excavation, and transportation of fill materials. Temporary visual impacts would result from earth-moving activities (traffic, noise, staging area, and dust) which could disrupt use of the area. However, all disturbed areas would be restored following remediation.

Socioeconomic and Institutional Issues

Community and Institutional Issues. Consolidation at Plant 2 would have an impact on Mallinckrodt Inc.'s ability to expand its operations. This could result in reduced employment.

Public Services. Public utilities in the area are adequate to accommodate remedial activities required for Alternative 3. The industrial nature of the SLDS location is designed for water, sewer, and power demands of industrial users. Emergency services in the area are adequate to respond to an incident or accident involving radioactive materials. USACE would coordinate with the public health care services provided by the Department of Community and Medical Care, County Hospital, and public health officials and emergency medical services to ensure that emergency response channels and facilities are appropriate for the maximum credible emergency that may occur. Local hospitals, Christian Hospital-Northeast and Barnes Hospital, are close to the downtown area and have personnel trained in procedures to deal with cases involving radiological contamination.

Transportation Impacts. For this alternative, little impact on transportation occurs during excavation and transport of the contaminated media to the consolidation area because the areas being considered for consolidation and capping are within the boundaries of SLDS. The transport of backfill could influence local traffic patterns.

Other potential impacts include personal commuting and business delivery delays, road deterioration from transporting heavy loads, and construction of temporary roads for transport to the containment area. Noise, fugitive dust, and engine exhaust might also be increased. The potential exists for some businesses or commercial districts, located near the excavation and construction activities, to be affected by access problems. Mitigative measures to lower impacts would include informing the owner and assisting in customer notification, identifying alternative routes into businesses, minimizing disruption during peak traffic periods by working off-hours and providing traffic flow control personnel, and utilizing periods of business closings such as vacation and inventory periods.

Unavoidable Adverse Impacts and Mitigative Measures

Community issues would be mitigated by a well-planned public information and community relations program to ensure that community members, property owners, and local officials are well-informed about the various steps in the alternative and progress being made toward completion of the action. Coordination and formal agreements with local officials may be necessary to mitigate institutional impacts associated with restrictions on land uses.

Short-term negative effects on surface water, wetlands, and air quality during excavation would occur. These effects include increased surface water runoff and erosion during excavation activities that could affect surface water quality and aquatic species in the river. These impacts would be minimized by using proper drainage controls and silt fences. There would be a short-term loss of habitat, and there would be some displacement and mortality of small mammals. Site restoration and revegetation would allow repopulation of terrestrial biota by natural successional processes. Increased fugitive dust emissions would affect ambient air quality, but the effect would be minimized by the use of appropriate dust suppression methods such as wetting, limiting truck speeds, and discontinuing operations above critical wind speeds. Temporary increases in traffic from heavy equipment operations and dump truck traffic could cause some delays and traffic congestion. Scheduling heavy equipment operations during non-rush hours and coordinating transportation routes in cooperation with the affected communities would minimize these effects.

The short-term impacts to workers, the general public, and the environment would be minimized by using project health and safety plans, protective equipment, limited access to construction/excavation areas, continuous air and water monitoring of the work environment and surrounding vicinity, and appropriate response to any measured releases.

The short-term effect of accidental spillage (release) of contaminated material during transport of contaminated material for disposal would be minimized by using covered trucks, contingency plans, and decontamination and inspection of trucks before leaving the site.

Other additional unavoidable adverse impacts and mitigative measures would occur due to onsite disposal activities. An operations plan (including cap inspections and groundwater, surface water, and air monitoring) would be in place to ensure monitoring of long-term onsite disposal integrity. Contingency plans would be developed to address any loss of onsite disposal integrity and/or release of disposed materials. A temporary increase in traffic of less than one percent would occur during remedial activities. Land use at properties not completely remediated under this alternative would continue to be restricted.

Short-Term Uses and Long-Term Productivity

The short-term effect at the downtown area includes the loss of small animal habitat on the city property [approximately 1.6 ha (4 acres)], and increased noise levels, traffic, and dust during site excavation. In the long-term, natural vegetation on the city property would be re-established and the remediated areas would be released for future industrial or commercial development. The construction of a cap would require long-term commitment of land.

Cumulative Impacts

In addition to the offsite/other organization activities discussed under the cumulative impacts for Alternative 2, there are specific impacts unique to Alternative 3. The incremental impacts on local traffic would be temporary and would cease with completion of construction activities. The excavation, hauling, and capping activities would add incrementally to any exhaust emissions and fugitive dust generated by other activities in the area. The cumulative impacts of these activities are not expected to significantly degrade air quality in the area given use of appropriate vehicular controls and dust suppression measures. No other potentially significant cumulative impacts are expected to occur.

5.2.3.6 Implementability

There are no technical problems that would limit the implementability of this alternative. Excavation of contaminated soils, construction of temporary roads, and truck transport of soil are conventional activities in construction projects of this kind.

Remedial actions have been successfully completed at many radiologically contaminated sites throughout the United States, including Acid/Pueblo Canyon, Los Alamos, NM; Albany Research Center, Albany, OR; Bago Canyon, Los Alamos, NM; Kellox/Pierport, Jersey City, NJ; Niagara Falls Storage Site, Lewiston, NY; Middlesex Municipal Landfill, Middlesex, NJ; National Guard Armory, Chicago, IL; University of California, Berkeley, CA; University of Chicago, Chicago, IL; and Elza Gate, Oak Ridge, TN. As a result of performing these remediations, technical procedures have been developed and established that will allow for straight-forward implementation of the proposed remedial actions.

Construction and operation of the components of Alternative 3 would be straightforward. Resources are readily available for removing contaminated soil, reducing the volume or size of structural material, and constructing an onsite cap. Standard excavation/construction equipment would be used to remove contaminated material and to construct the disposal facility. Special engineering techniques involving precautions on excavation near buildings and structures would be observed during remediation.

The application of decontamination and dismantlement techniques to contaminated building surfaces and the construction of physical barriers are straightforward and reliable. The decontamination of Building 25 would require trained personnel and specialized equipment for physical and chemical decontamination that are readily available commercially. The choice of decontamination technology would be based on the level of radioactivity and the characteristics of the surface to be decontaminated. Decontamination, dismantling, and restoration activities at SLDS would occur at a time that would not disrupt ongoing plant operations.

The area available for the onsite disposal of contaminated material is limited. Approximately 2.3 ha (5.7 acres) are available for an onsite cap at Plant 2. Approximately 4 ha (10 acres) of the site would be impacted during remedial action activities for support facilities.

Disposal of the waste in an engineered disposal facility incorporating design features that have been used in other facilities to dispose of wastes similar to those at SLDS is considered a reliable process. A land-based disposal facility, with containment in the form of a designed cover system would provide significant and reliable isolation of the waste from the environment. The procedures and equipment for designing and constructing a disposal facility for material such as the SLDS waste are well established and would be straightforward to implement. Additional studies might be required to determine optimal waste placement and compaction methods as part of the detailed design and optimization of the disposal operation (BNI 1989a).

Construction techniques used for capping are not expected to be difficult to implement. Testing and engineering to address subsidence are well established civil engineering practices (BNI 1994). The clay cap must be placed and compacted in layers to ensure that the proper moisture/density relationship and low permeability is achieved. Identification and permitting of a suitable clay source could be expensive and time consuming. Capping is a well-established technology that has been used at many contaminated waste sites. Capping has been employed for many sites where permanent containment of large volumes of contaminated soils is required. In particular, this approach is employed at a number of radiologically and chemically contaminated sites (eg, Fall City, TX; Lowman, ID; Grants, NM; Missouri Electric Works, MO; Conservation Chemical, MO; White Farm Equipment Pump, IA; Wheeling Disposal Service, MO; Lawrence Todrz Farm, IA; and Tooele Army Depot, UT).

Institutional controls would have to be implemented to restrict access to consolidated soils. Long-term environmental monitoring of groundwater and radon emissions would be required around the capped area. Traffic would be diverted during road remedial actions.

The effectiveness of the main components of remedial activities under Alternative 3 would be maintained. An environmental monitoring program for SLDS groundwater involves use of readily available technologies and techniques. The proposed monitoring plan, the reliability, and availability of environmental monitoring are described in Sections 5.2 and B.1.3. Any rainwater runoff generated during the waste consolidation in the disposal area would be captured by a runoff collection system, tested, and if needed, treated before discharging. The disposal cap would be visually inspected periodically to identify and repair any areas of erosion, animal burrowing activities, or deep root growth. Radon emanation would also be monitored after closure to ensure compliance with release standards. Survey markers would be placed on the disposal cap to aid in assessing settling. Groundwater monitoring wells would be located to detect changes in groundwater quality. The monitoring system associated with the capped disposal area would provide the information needed to determine if corrective action should be taken to prevent the migration of contaminants into the environment. Sampling would be performed annually for air for radon, groundwater, stormwater and NESHAPs to monitor the capped disposal facility.

The implementation of Alternative 3 would not adversely impact the performance of additional remedial actions that might be required in the future at the St. Louis site. The ability to remediate groundwater would not be impacted by the presence of the capped disposal site. Implementation would be over approximately five years.

5.2.3.7 Cost

The costs of this alternative include excavation of accessible contaminated soils from SLDS and all vicinity properties in the downtown area; transporting excavated soil and debris to a consolidation and capping location; construction and maintenance of a clay cap; and decontamination and dismantlement of contaminated building structures. To provide comparability across the alternatives, the cost estimates assume that inaccessible soils would be remediated as they became available. Because the consolidation area is expected to be closed before inaccessible soils are remediated, inaccessible soils will be sent to off-site disposal. For costing purposes, it is assumed that the inaccessible soils are excavated and shipped concurrent with excavation and consolidation of accessible soil. These assumptions provide a reasonable mechanism for bounding the total site remediation costs while not substantively affecting the evaluation of alternatives. The 30 year cost to implement the Alternative 3 remedial action is $100 million (Appendix B). The 30 year cost of not implementing any remedial action per Alternative 1 is $22 million (Appendix B). The difference in 30 year cost between Alternative 3 and Alternative 1 is $78 million. O&M costs include temporary clay cover maintenance during the initial site subsidence phase and environmental monitoring from initiation of the remediation phase through completion of the post-closure confirmatory process. The long-term environmental monitoring program described in Section 5.2 constitutes most of this O&M cost. Supporting information on the costs is provided in Appendix B.

5.2.4 Alternative 4 – Partial Excavation and Disposal

This alternative includes excavation of all accessible soils and sediment contaminated: above the composite criteria in the top two feet at SLDS; above the ALARA criteria from 2 ft down except at Plant 7 where composite criteria would be observed to depth, because of the high radium concentrations at Plant 7. Material below composite criteria would be used as backfill, provided it does not exhibit hazardous characteristics. At depths greater than 2 ft, material below the ALARA criteria may be used as backfill. Excavated soils above the cleanup criteria and debris would be disposed in an appropriate disposal facility. Excavated soil below the composite criteria would be used as fill, provided it does not exhibit hazardous characteristics.

Inaccessible soil would remain in place beneath the buildings, railroads, and other structures and would be managed by institutional controls until a remedy for inaccessible soils is selected. Radon control measures would be coupled with institutional controls as necessary to reduce the potential for human exposure. The contaminated building surfaces described for Alternative 3 would be decontaminated when the owner made the buildings available. For the purpose of estimating costs, it is assumed that the buildings are made available during the accessible soils remediation time period. Groundwater would also be addressed as described in Alternative 3. In addition, the cost estimates assume inaccessible soils would be excavated and disposed concurrent with remediation of accessible soils according to the same criteria.

5.2.4.1 Overall Protection of Human Health and the Environment

Alternative 4, partial excavation and disposal, is protective of human health and the environment. The risk of exposure to site-related contamination would be reduced to levels acceptable under current use and industrial future use scenarios. This would be accomplished through removal of the most contaminated soils and use of institutional controls to limit the potential for future exposure to residual radioactivity. Based on the analysis in Appendix C, the sitewide average residual cancer risk for the industrial/construction worker is approximately 4 × 10^{-5} for the anticipated future use conditions (including 6 inch cover and use of composite criteria at Plant 7).

Under Alternative 4 long-term effectiveness and permanence would be achieved because accessible soils and sediments posing potentially unacceptable risks to human health and the environment would undergo excavation and disposal. This alternative would prevent human exposure to soil exceeding ALARA criteria by means of permanent disposal at a regulated waste disposal facility. This alternative would also protect groundwater by removing concentrated potential sources of soil contamination from contact with water.

Under Alternative 4, the community and workers would experience increased adverse effects due to excavation of the contaminated soil. Short-term effects on the community would occur during excavation of contaminated soils, dismantlement of buildings, and transportation of soils and debris. Air quality would be affected by the releases of particulates and radon gas into the atmosphere during excavation of soils. The extent of exposure depends on many variables, such as the surface area exposed, degree of soil agitation or movement, radionuclide concentration, rate of air movement, temperature, and humidity. Occupational radiation doses to remedial workers would result from direct exposure to gamma radiation from contaminated soil and from ingestion and inhalation of airborne contaminated particulates. Site excavation workers exposure would be assessed and controlled through training, medical surveillance, environmental monitoring, and strict adherence to a site health and safety plan. The dose to the public would be maintained well below NRC's limit for members of the general public (10 CFR 20) during remediation. The dose to both workers and the public would be reduced to the lowest level reasonably achievable.

Residual radioactive contamination would be removed from affected buildings by means of decontamination and dismantlement as described under Alternative 3. Similarly, occupancy and use restrictions and engineered control measures would also be implemented for buildings where radon gas is a concern.

Onsite remedial activities associated with Alternative 4 are very similar to those described for Alternative 3, except for the higher cleanup criteria (and lower volumes) for the excavation of contaminated soil which reduces the short-term impacts to remedial workers. The calculated non-radiological construction-related risk of fatality that may occur during implementation of Alternative 4 is 0.002.

Transportation risks would be greater for Alternative 4 because of the increased hauling distance. Out-of-state disposal options increase transportation risk with increased distances.

Under Alternative 4, compliance with ARARs would be achieved through institutional controls that would be implemented to restrict and regulate access to contaminated soils and groundwater. Groundwater monitoring and institutional controls would cease in areas where the source term had been remediated and protection of human health and the environment is demonstrated by risk assessment. A long-term management plan would ensure that institutional controls would continue to adequately protect human health and the environment. Residual radioactive contamination would be removed from affected buildings by means of decontamination and dismantlement as described under Alternative 3. Similarly, occupancy and use restrictions and engineered control measures would also be implemented for buildings where radon gas is a concern.

5.2.4.2 Compliance with ARARs

ARARs would be achieved. This alternative would comply with applicable guidance for permissible levels of residual radioactivity through a combination of excavation of the highest concentrations and use of institutional controls. For the soil below two feet in depth, dose and risk based supplemental standards would be used to demonstrate compliance with 40 CFR 192.22. Public doses of less than 25 mrem/yr as required by 10 CFR 20 Subpart E would be achieved through land use restrictions. The residual risk would be below the 3×10^{-4} recommended by OSWER Directive 9200.4-23.

In Alternative 4, ARARs are met through a combination of excavation of the most contaminated soil and institutional controls to minimize human exposure to residual contamination. Thus, the exposure of a SLDS industrial worker due to contaminated soil is the pathway of concern and presents a risk ranging from 8.6×10^{-5} to 3.5×10^{-5} depending on work location (Appendix C). Analogous to Alterative 3, use of active and passive radon control systems and adherence to worker safety regulations will be used to maintain safe work levels for all SLDS employees.

5.2.4.3 Long-Term Effectiveness and Permanence

This alternative is permanent for the soil excavated and disposed offsite. Human health and the environment are protected as long as the institutional controls can be implemented. Even if control of the site is lost in the future, the dose would be less than 100 mrem to the maximally exposed individual as required by 10 CFR 20.1403.

Disposal would be at an approved waste disposal facility. The owner of the facility would be responsible for the monitoring and maintenance activities to ensure effectiveness of waste isolation and to prevent any potential exposures if the disposal cell failed.

Irreversible and Irretrievable Commitment of Resources

Use of backfill and consumption of petroleum products would occur during implementation of Alternative 4. The use of backfill for of this alternative would be similar to that of Alternative 3. The consumption of petroleum products would increase with transportation distance to the disposal facility.

Disposal sites involve the long-term restricted use of land. The commitment of land to restricted disposal use is theoretically not irreversible because the affected property could be remediated in the future. However, it is assumed that the selected disposal site will remain committed to disposal. The disposal site would be used for purposes of disposal regardless of whether Alternative 4 is implemented or not. Thus the commitment of resources could be considered consumption of disposal capacity rather than commitment of land use. Perpetual care will be taken of the committed land as required. For example, the cover will be visually inspected and groundwater will be monitored.

5.2.4.4 Reduction of Contaminant Volume, Toxicity, or Mobility through Treatment

Although treatment and volume reduction technologies would be assessed, this alternative does not claim to reduce the volume, toxicity, or mobility of contaminated soil because no treatment is currently planned prior to ultimate disposal. However, treatment is being retained as a conditional component of this alternative. If a treatment technology is demonstrated to be cost effective and regulatory approval can be obtained, then treatment may be added as an adjunct to excavation. Ultimate disposal of the accessible and inaccessible soil would reduce the mobility of contaminants by denying infiltration into contaminated soil, by reducing fugitive dust emissions, and by eliminating offsite surface runoff. Building decontamination would eliminate fugitive dust emission.

5.2.4.5 Short-Term Effectiveness and Environmental Impacts

Effects on Community and Workers

Onsite remedial activities associated with Alternative 4 are very similar to those described for Alternative 3, except for the reduced soil volume and the construction of the cap. Consequently, short-term impacts on the community and remedial workers for Alternative 4 are slightly less than those discussed for Alternative 3. Using the NUREG/CR-1266 rate for the number of construction-related fatalities, the calculated construction-related risk of a fatality that may occur is 0.0020.

Environmental Impacts

Potential environmental impacts of Alternative 4 onsite activities are similar to Alternative 3 (Section 5.2.3.5), with exceptions discussed below.

Geology and Soils. Excavated areas would be backfilled, recontoured, and revegetated or paved to control surface water runoff. Borrow material needed for backfill would be obtained from offsite sources and procured as a commodity in accordance with government procurement regulations in effect at the time of the remedial action. Potential borrow material sources that can meet the expected demands can be found in the St. Louis area. Some ecological impacts may be experienced at the borrow site location to inhabitants of the ecosystem.

Standard mitigative measures by the disposal facility operators would be used to reduce the potential for erosion during construction and operation of the facility. Good engineering practices by the disposal operation would also be used to reduce the potential for water erosion, and mitigative measures would be used as needed.

In the absence of an accident, transportation of the waste would have little effect on offsite soil. Contingency plans would be in place to address spills, so if an accident occurred that resulted in the release of contaminated material, the spill area would be cleaned up promptly; thus, no long-term effects are expected.

Water Quality/Resources. For onsite activities, this alternative would affect water quality in the same manner as for Alternative 3. Alternative 4, like Alternative 3, would have a short-term negative effect on surface water quality due to surface runoff. Treatment of groundwater from dewatering of extracted soil will serve to alleviate the localized groundwater contamination conditions. The proposed monitoring plan, the reliability, and availability of environmental monitoring are described in Section 5.2.

The disposal facility would be protective of groundwater and surface water.

Adverse effects on surface water or groundwater related to transportation are unlikely except in the event of an accident. If an accidental release occurred, it would be cleaned up in accordance with the contingency plan, to prevent potential movement of contaminated material to any nearby water body.

Biotic Resources. The short-term effects during soil excavation would produce the same slightly negative effect at SLDS for Alternative 4 as described for Alternative 3.

Impacts to biota at the commercial borrow soil location(s) cannot be assessed since this commodity will be procured from an unknown source at the time of remedial action.

At the disposal facility, some wildlife in the vicinity of the site could be temporarily affected by noise, human activity, and fugitive dust associated with construction of the disposal cell, transport of the waste to the site, and placement of the waste into the cell. Potential impacts from fugitive dust emissions would be minimized through the implementation of dust control measures during construction and transportation activities.

Threatened and Endangered Species. The effects of Alternative 4 onsite activities on threatened and endangered species are the same as those for Alternative 3. An approved disposal facility will be used that is fully compliant with applicable federal laws.

Wetlands Impacts. Alternative 4 is not expected to have any impact on wetlands.

Floodplains Impacts. The effects of Alternative 4 onsite activities on the floodplain are the same as those for Alternative 3 because work is being performed in the same floodplain area for these alternatives. However, there is no consolidation and capping onsite in Alternative 4; thus, floodplain impacts would be reduced.

No floodplain impacts are expected at the disposal facilities. Existing regulations governing disposal facilities and specific provisions of a disposal facility's permit are expected to mitigate any potential impacts of disposal on floodplains.

Air Quality. The effects of Alternative 4 onsite activities on air quality are similar to those described for Alternative 3. Impacts on offsite air quality during transportation and disposal are expected to be negligible.

Archaeological, Historical, and Cultural Resources

The effects of implementing Alternative 4 are even less than Alternative 3 because less excavation reduces the chances of disturbing indian burial grounds. Excavations are unlikely to affect cultural resources. This alternative would not affect any known archaeological resources other than those already addressed in Alternative 3.

Disposal facility operations are unlikely to disturb historical, archeological or cultural resources by accepting these wastes.

Land Use and Recreational/Aesthetic Resources

The effect on land use from implementing Alternative 4 would be similar to Alternative 3 except that restrictions on digging would be maintained in some areas.

No significant effects will occur on land use as a result of offsite disposal because existing disposal sites would receive the waste.

Socioeconomic and Institutional Issues

Community and Institutional Issues. Community and institutional issues for Alternative 4 onsite activities are similar to Alternative 3 (Section 5.2.3.5). Short-term impacts in the form of annoyance, inconvenience, and disruption of activities would occur during excavation and transportation activities. Coordination with local officials and property owners would be undertaken to minimize disruption to the extent possible. USACE would coordinate with the management of Mallinckrodt Inc. to minimize impacts on operations and workers during remediation.

Public Services. Public services are similar to those described under Alternative 3 (Section 5.2.3.5).

Transportation Impacts. The principle effects on local road transportation and traffic are similar to those indicated in Alternative 3. The principal differences between Alternative 3 and 4 regarding transportation impacts involve the reduced volume to be excavated for Alternative 4 and the railroad transport of wastes for offsite disposal. These soils would be transported from local railroad sidings to offsite disposal; therefore, no local roadway transportation increase would occur. Risk of fatality to a member of the public is 0.013.

Unavoidable Adverse Impacts and Mitigative Measures

Short-term environmental effects during implementation of Alternative 4 onsite activities are similar to those described for Alternative 3. Adverse activities and impacts associated with disposal would involve transportation to and handling at the disposal site. Operational plans, contingency plans, and mitigative cleanup measures would be developed to address mishaps en route or at the disposal location. Land use at the disposal site would be restricted.

Short-Term Uses and Long-Term Productivity

The short-term and long-term effects associated with Alternative 4 include loss of small animal habitat in excavation areas and increased noise, traffic, and dust during site remedial activities similar to Alternative 3. Current uses would be re-established at the conclusion of remedial activities.

Cumulative Impacts

Rail and heavy equipment activity associated with the movement of excavated soils to an offsite disposal facility would incrementally increase local traffic volumes and noise. This incremental impact would be temporary in nature, ceasing with the completionofremedial activities. Air quality would be incrementally affected by exhaust emissions of traffic, and additional fugitive dust would result from the activities. These cumulative impacts would be temporary in nature and would cease with completion of remedial activities.

5.2.4.6 Implementability

Construction and operation of the removal and disposal components of Alternative 4 would be straightforward. The majority of the activities requiring implementation for Alternative 4 are comparable to those for Alternative 3 (ie, institutional controls, soil excavation, truck transport of soil, and environmental monitoring). Readily available resources and standard procedures are available for waste disposal. The implementability of the disposal options are straightforward processes involving common technologies.

The implementability of the offsite disposal option component of Alternative 4 would also depend on the implementability of bulk transport of the waste to the offsite location. The use of railroads to haul bulk material (ie, coal, dirt, rock) is a common practice. Some special handling of the contaminated soil would be required but should be straightforward and readily implementable. State and federal regulations would need to be addressed, and licenses, permits, and administrative procedures would need to be in place before transport and disposal could take place.

Offsite transport of the contaminated material to the disposal site would consist of either truck transport from SLDS to the disposal site or transfer of the material to rail cars and rail transport to the low-level waste disposal facility. Equipment, facilities, and the required personnel for truck and rail transport are readily available. The waste would be shipped in standard gondolas.

SLDS has several existing sidings, and the railroad owner could potentially assist in locating a siding that could be used for staging and loading. Construction and operation of a rail siding, if needed, would be straightforward. Material staging and loading would be accomplished with standard, industry-proven technologies.

The substantive requirements for a permit for the construction and operation of the rail siding would be met. Information pertinent to shipment of the SLDS waste (eg, waste characteristics and emergency handling information) would be entered into the railroad computer system for access by the railroad emergency response teams, if needed. A spill contingency plan would be developed and, in the event of a spill, an emergency response team would reload the spilled material into containers, test the area for residual contamination, and remediate the area, as needed. Transport of the waste offsite would require significant coordination among agencies. In the case of permitting, the substantive, but not the administrative, requirements would be met.

The administrative feasibility of Alternative 4 would be impacted for the offsite disposal options by the requirements for coordinating offsite transport and disposal. Numerous federal regulations, licenses, permits, and administrative procedures would need to be addressed before transport and disposal could take place. These requirements might impact the time required to implement this alternative.

5.2.4.7 Cost

The total capital cost of this alternative includes excavation of contaminated soils, transportation, and disposal of contaminated soils and debris. The total 30-year cost of this alternative, which is dependent on the disposal option selected, is estimated to be $92 million (Appendix B). The cost difference between Alternative 4 and the cost of not implementing any remedial action per Alternative 1 is estimated at $78 million (Appendix B). Long-term onsite environmental monitoring constitutes most of the O&M cost for this alternative. The O&M environmental monitoring costs are from initiation of the remediation phase through completion of the post-closure confirmatory process. Supporting information is provided in Appendix B. As with Alternative 3, inaccessible soils are included in the cost and it is assumed that the same remedy will be chosen for accessible and inaccessible soils.

5.2.5 Alternative 5 – Complete Excavation and Disposal

This alternative includes excavating all accessible soils contaminated above composite criteria. Material incidentally excavated below the composite criteria could be used as backfill to replace the contaminated material, provided it does not exhibit a hazardous characteristic. A separate remedy for inaccessible soils under buildings at SLDS, under the railroads, and other permanent structures would be selected under separate documentation. Building decontamination and partial demolition would also be performed under this alternative when the building becomes available. Annual monitoring would continue until a remedy is selected for inaccessible soils.

The evaluation of this alternative is the same as that described for Alternative 4, except as noted below.

5.2.5.1 Overall Protection of Human Health and the Environment

Alternative 5, Complete Excavation and Disposal, is protective of human health and the environment. The risk of exposure to site-related contamination would be reduced to levels acceptable under current use and plausible future use scenarios.

Under Alternative 5, long-term effectiveness and permanence would be achieved through excavation and disposal of accessible soils posing potentially unacceptable risks to human health and the environment. Institutional controls would be used for inaccessible soils to prevent human exposure. This alternative would prevent human exposure to accessible contaminated soil, sediment, and debris by means of permanent disposal at a regulated waste disposal facility. The excavation and disposal of contaminated soil would also protect groundwater by removing the source of potential future groundwater contamination.

Onsite remedial activities associated with Alternative 5 are very similar to those described for Alternative 4, except that the criteria for removal would be more stringent. Short-term impacts on the community and remedial workers for Alternative 5 are greater than those presented for Alternative 4 (Section 5.2.4.5) due to the increased volume and depth.

The community and workers would experience increased adverse effects over Alternative 4 due to excavation of a larger volume of soil. Short-term effects on the community would occur during excavation of all contaminated soils; transportation of soils, and disposal activities. Air quality would be affected by releases of particulates and radon gas into the atmosphere during excavation of soils. The volume released depends on many variables, such as the surface area exposed, degree of soil agitation or movement, radionuclide concentration, rate of air movement, temperature, and humidity. Occupational radiation doses to remedial workers would result from direct exposure to gamma radiation from contaminated soil and from ingestion and inhalation of airborne contaminated particulates. Excavation workers' exposure would be controlled through training, medical surveillance, environmental monitoring, and strict adherence to a site health and safety plan.

Residual radioactive contamination would be removed from affected buildings by means of decontamination and dismantlement as described under Alternative 3 at some time in the future when the owner makes the building available. Until then, occupancy and use restrictions would be imposed to keep current worker exposures at a minimum. Similarly, occupancy and use restrictions and engineered control measures would also be implemented for buildings where radon is a potential concern.

Transportation risks would be greatest for Alternative 5 because the largest volume of soil would be excavated and transported for disposal. Out of state disposal options increase transportation risk as distances increase. Short-term risk considerations for the Alternative 5 disposal options are analogous to those presented under Alternative 4.

Similar to Alternative 4, compliance with ARARs would be achieved through institutional controls that would be used as a precautionary measure to prevent unauthorized use of site groundwater for any reason at sites retaining contaminated soil. Unlike Alternatives 3 and 4, however, these controls will be needed only until the source of contamination is removed from a given area and protection of human health and the environment is demonstrated by risk assessment.

5.2.5.2 Compliance with ARARs

ARARs would be achieved as discussed for Alternative 3, Section 5.2.3.2. Institutional controls would be used for inaccessible soils and groundwater at the site and would be left in place until a remedy for inaccessible soils is selected.

In Alternative 5, the current worker radiological exposure is the same as for Alternatives 3 and 4. However, the SLDS construction worker exposure would be reduced by application of the more stringent cleanup criteria. As in Alternatives 3 and 4, use of active and passive radon control systems and adherence to worker safety regulations will be used to maintain safe working conditions in the occupied buildings.

5.2.5.3 Long-Term Effectiveness and Permanence

The long-term effectiveness of Alternative 5 would be greater than that for Alternative 4, but is essentially indistinguishable from Alternative 4 if at least 15 cm (6 in.) of soil is preserved over the contaminated zone. In addition, removing the inaccessible soils to the composite criteria would be protective of human health under future risk scenarios without dependence upon institutional controls. This alternative is permanent for the media it addresses because materials that pose a health risk would eventually be removed and placed in a permanent off-site disposal facility. Therefore, no long-term management of soils or buildings would be required on the SLDS site. Monitoring efforts would continue during remediation until all contaminated soils and building debris are removed from existing locations.

Irreversible and Irretrievable Commitment of Resources

Greater use of backfill and petroleum products would be required for implementation of Alternative 5 than for Alternative 4. A larger volume of material would be excavated resulting in a larger backfill volume. Backfill and petroleum products are available locally, and their consumption should be met using local supplies.

5.2.5.4 Reduction of Contaminant Volume, Toxicity, or Mobility through Treatment

Treatment and volume reduction technologies would be assessed, and if a treatment technology is demonstrated to be cost effective, it would be incorporated into the alternative as an adjunct to excavation, providing regulatory approval is granted. Alternative 5 would not reduce the volume, toxicity, or mobility of contaminated soil as discussed here because no treatment is planned prior to ultimate disposal. However, the complete removal and disposal of all contaminated material will eliminate all non-disposal sources of runoff, infiltration, fugitive dust, and emissions.

5.2.5.5 Short-Term Effectiveness and Environmental Impacts

Effects on Community and Workers

Onsite remedial activities associated with Alternative 5 are very similar to those described for Alternative 4, except that an additional volume of contaminated soil would be remediated due to the application of more stringent cleanup criteria. Short-term impacts on the community and remedial workers for Alternative 5 are thus somewhat greater than those presented for Alternative 4 (Section 5.2.4.5). The dose to the remedial worker is estimated at 728 mrem during the project. This is not taking personal protective equipment into consideration, thus the actual dose would likely be much lower. This worst-case occupational dose would result in an increase in lifetime cancer risk of 5×10^{-3}, or about 5 in 1000.

Non-radiological occupational hazards associated with Alternative 5 would be higher than those encountered under Alternative 4. Using the NUREG/CR-1266 rate for the number of construction-related risk of fatality, the calculated construction-related fatality risk during implementation of Alternative 5 is 0.0056.

Worker exposure pathways for radiological risks would be maintained at safe levels through continued compliance with federal safety regulations. Effects on community and workers during transportation depend on the distance to the disposal facility. The risk of fatality associated with waste transport is 0.086. Adherence to federal regulations, particularly worker safety programs, will be used to minimize these risks.

Environmental Impacts

The environmental impacts of implementing Alternative 5 are similar to Alternative 4 except that a larger volume of soil would be excavated. The additional Alternative 5 impacts are discussed below.

Geology and Soils. Excavation under this alternative would result in the removal of all the soil described in Alternative 4 and in addition, soil would be removed in accordance with the more stringent composite criteria regardless of the depth of contamination. Excavated areas would be backfilled with overburden material below the composite criteria, recontoured, and revegetated or paved to control surface water runoff. Additional approved borrow material needed for backfill would be obtained from offsite sources and procured as a commodity in accordance with government procurement regulations in effect at the time of the remedial action. Potential borrow material sources that can meet expected demands can be found in the St. Louis area. Some ecological impacts may be experienced at the borrow site location to inhabitants of the ecosystem.

Water Quality/Resources. Implementing Alternative 5 would remove the existing potential source of contamination for leaching into groundwater. Since this alternative involves a phased action for removing inaccessible soils, the potential for contaminant infiltration leaching into groundwater would exist until all inaccessible soil is removed. This alternative would have a short-term negative effect on surface water quality from increased silt and sediment loading carried in surface runoff from excavation areas. Proper construction practices and erosion controls would minimize these effects. Treatment of groundwater from dewatering of extracted soil for discharge will serve to help alleviate the localized groundwater contamination conditions. Also, groundwater quality would gradually improve over baseline conditions because the source of contaminant leaching would be removed. The proposed monitoring plan and the reliability and availability of environmental monitoring are described in Section 5.2. If radiological contamination is not detected after 5 years of monitoring, the annual samples would be discontinued.

Biotic Resources. The effects would be similar to Alternative 4.

Threatened and Endangered Species. The effects of Alternative 5 on threatened and endangered species are the same as those for Alternative 3.

Wetlands Impacts. No wetlands would be disturbed by implementation of Alternative 5.

Floodplains Impacts. The effects of Alternative 5 on the floodplain are the same as those for Alternative 4.

Air Quality. The effects of Alternative 5 on air quality are similar to those described for Alternative 3.

Archaeological, Historical, and Cultural Resources

The effects of implementing Alternative 5 are comparable to those discussed in Alternative 3.

Land Use and Recreational/Aesthetic Resources

The effect on land use would be similar to Alternative 4. Land use at inaccessible soil locations would be restricted until the remedy for inaccessible soil is selected.

Socioeconomic and Institutional Issues

Community and Institutional Issues. Community and institutional issues for Alternative 5 are similar to those described under Alternative 4 (Section 5.2.4.5). Additional coordination would be necessary with property owners where inaccessible soils are located to schedule remediation at a time that will not interfere with the operations of the facilities. Coordination with local officials, railroad company officials, property owners, and other impacted entities would be needed in order to minimize impacting their operations during removal of inaccessible soils.

Public Services. Public services are similar to those described under Alternative 4 (Section 5.2.4.5).

Transportation Impacts. The principal activities in Alternative 5 are comparable to those in Alternative 4, but would tend to be more prolonged due to the increased volume of soil.

Unavoidable Adverse Impacts and Mitigative Measures

Short-term environmental effects during implementation of Alternative 5 are similar to those described for Alternative 3.

Short-Term Uses and Long-Term Productivity

The short-term and long-term effects associated with Alternative 5 include the same loss of small animal habitat in excavation areas and increased noise, traffic, and dust during site remedial activities as Alternative 3.

Cumulative Impacts

No adverse cumulative impacts are anticipated from implementation of Alternative 5.

5.2.5.6 Implementability

All the activities requiring implementation for Alternative 5 are comparable to those for Alternative 4. The only change is the volume of contaminated media to be excavated and disposed and the criteria for removal. The increase in volume between Alternative 4 and 5 would increase the time required to implement this alternative. An environmental monitoring program for SLDS groundwater, sediment, and surface waters during remediation involves use of readily available technologies and techniques. The proposed monitoring plan, the reliability, and availability of environmental monitoring are described in Section 5.2. Groundwater monitoring would be discontinued after 5 years if no migration of radiological contaminants is detected. Radon monitoring would only be performed in occupied buildings that present a potential radon hazard.

The administrative feasibility of Alternative 5 would be impacted by the requirements for coordinating offsite transport and disposal. Numerous federal regulations would need to be addressed, and licenses, permits, and administrative procedures would need to be in place before transport and disposal could take place. These requirements might impact the time required to implement this alternative.

5.2.5.7 Cost

The total capital cost of this alternative would include excavation of all soils, decontamination of building surfaces, transportation, and disposal of contaminated soils. The total 30-year cost of this alternative, which is dependent on the disposal option selected, is estimated to be $140 million (Appendix B). Transportation and disposal costs would depend on the disposal option chosen, the cost may be less if a different class of disposal facility is chosen. The cost difference between Alternative 5 as a function of disposal option and the cost of not implementing any remedial action per Alternative 1, which costs $22 million (Appendix B), is estimated at $118 million. Long-term onsite environmental monitoring, as described in Section 5.2, constitutes most of the O&M cost for the onsite alternative. O&M costs include environmental monitoring during the remediation phase and are assumed to continue at SLDS until all inaccessible soils have been removed and disposed of at a commercial disposal facility. Supporting information is provided in Appendix B. It is assumed that the same remedy would be selected for accessible and inaccessible soils and that overlying structures are removed before excavation.

A separate cost assessment was performed to evaluate the effect on cost of sending all excavated material, including overburden below composite criteria, to off-site disposal. If soils below the composite criteria are not reused, the cost of this alternative increases to $170 million.

5.2.6 Alternative 6 – Selective Excavation and Disposal

This alternative focuses on reducing the need for future federal studies, designs, and remedial actions. In this alternative, soil contaminated above the composite criteria would be excavated in the top 4 ft across the site, except for the columbium-tantalum processing area beneath Plant 5. The boundary of this area would be delineated prior to beginning remedial activities. Excavation at Plants 1, 2, 3, 8, and 9 and at the former location of Buildings 116, 117, 704, 705, 706, and 707 at Plants 6 and 7 would be extended to 6 ft. Below 4 ft (6 ft in the designated areas), excavation would be determined by the derived ALARA criteria. Soil below the ALARA criteria would be used to backfill the deep excavation areas (deeper than 4 or 6 ft) with the excess being disposed off-site. Only approved borrow would be used as backfill above the 4 to 6 ft depth. The total in situ volume of soil to be removed would be much greater than in Alternative 4 but less than in Alternative 5. This volume is intended to be used as a basis for estimating cost and should not be interpreted as a final volume to be removed. Actual volumes may be greater or less than those estimated. Soil exceeding the ALARA criteria would be shipped offsite to an appropriate disposal facility. Soil below the ALARA criteria exceeding the volume of excavated soil below 4 (or 6) ft would also be sent to an appropriate disposal facility. Only purchased approved borrow would be used as backfill above the 4 or 6 foot depths to return the excavated areas to grade. Institutional controls would be maintained for inaccessible soil under this alternative until a remedy for the inaccessible soils is selected.

5.2.6.1 Overall Protection of Human Health and the Environment

Alternative 4 was demonstrated to be protective of human health and the environment provided certain restrictions could be applied to limit the potential for exposure to radioactive soils. Alternative 6 would be more protective with fewer restrictions imposed. Construction activities could proceed without requiring radiological protections for workers. Land use restrictions would need to be maintained to prevent consumption of groundwater and to impose restrictions on excavation below the 4 and 6 ft depths. Future industrial/construction worker risks would be below the sitewide incremental cancer risk level determined for Alternative 4 (4×10^{-5}).

Alternative 6 would achieve long-term effectiveness and permanence by excavation and disposal of contaminated soil and sediments above ALARA criteria and reducing the accessibility of soils exceeding the composite criteria. Groundwater impacts would be reduced by the removal of the most concentrated soils.

The community and workers would experience increased adverse effects during the implementation of Alternative 6 due to the excavation of contaminated soil. Short-term effects would occur from excavation of soils, dismantlement of buildings, and transportation of soil and debris. Air quality would be affected by particulate and radon gas releases into the atmosphere during excavation and building dismantlement. This effect would be mitigated by the use of dust suppression measures. Occupational radiation doses to remedial workers would result from direct exposure to gamma radiation from excavated soil and from inhalation and incidental ingestion of airborne particulates. Worker exposure would be controlled through training, medical surveillance, environmental monitoring, and strict adherence to a site health and safety plan. The dose to the public would be maintained well below NRC's public exposure limit (10 CFR 20) and would probably not exceed background levels. Doses to both workers and the public would be held to the lowest levels reasonably achievable.

Remedial activities associated with Alternative 6 are very similar to Alternative 4, except for the greater depth of excavation for the more stringent criteria. The increased depth would result in increased volume of soil excavated and thus greater remedial worker exposure.

Like Alternative 4, Alternative 6 would rely on institutional controls to comply with ARARs. Institutional controls would be implemented to restrict and regulate access to contaminated soil and groundwater. Groundwater monitoring and institutional controls would cease in areas where the source term had been remediated and protection of human health and the environment is demonstrated by risk assessment. A long-term management plan would ensure that institutional controls continue to adequately protect human health and the environment until a remedy is selected for the inaccessible soils. This plan would be developed during the design phase and included in agreements with property owners. Occupancy and use restrictions and engineered control measures would be utilized to limit exposures to radon gas in buildings until the remedy for inaccessible soil is selected.

5.2.6.2 Compliance with ARARs

Alternative 6 would be in compliance with ARARs. Overburden and excavated soil between composite and ALARA criteria would have hazardous characteristic tests performed prior to use as backfill. This alternative would comply with applicable requirements for permissible levels of residual radioactivity through a combination of excavation of the most highly contaminated soil, removal of all soil above 40 CFR 192 requirements within the depth of likely intrusion, and institutional controls. Public doses would be less than required by 10 CFR 20 Subpart E. Residual risk would be below 3×10^{-4} as required by OSWER Directive 9200.4-23.

5.2.6.3 Long-Term Effectiveness and Permanence

This alternative is permanent for the soil excavated and disposed offsite. Human health and the environment are protected by institutional controls until a remedy for inaccessible soils is selected.

Disposal would be at an approved waste disposal facility. The owner of the facility would be responsible for the monitoring and maintenance activities to ensure effectiveness of waste isolation and to prevent any potential exposures if the disposal cell failed.

Irreversible and Irretrievable Commitment of Resources

Use of backfill and consumption of petroleum products would occur during implementation of Alternative 6. The consumption of petroleum products would increase as a function of transportation distance to the disposal facility.

Disposal sites involve the long-term restricted use of land. The commitment of land to restricted disposal use is theoretically not irreversible because the affected property could be remediated in the future. The selected disposal site would likely be used for purposes of disposal regardless of whether Alternative 6 is implemented or not. Thus the commitment of resources could be considered consumption of disposal capacity rather than commitment of land use. Perpetual care will be taken of the committed land as required. For example, the cover will be visually inspected and groundwater will be monitored.

5.2.6.4 Reduction of Contaminant Volume, Toxicity, or Mobility through Treatment

As in the other excavation alternatives, treatment would be a conditional part of the remedy. If treatment is demonstrated to be cost effective, and if regulatory approval can be obtained, then treatment could be made an adjunct of excavation. The mobility of the contaminants would be reduced as a result of disposal in a permanent disposal facility.

5.2.6.5 Short-Term Effectiveness and Environmental Impacts

Effects on Community and Workers

Onsite remedial activities associated with Alternative 6 are very similar to those described for Alternative 3, except for the reduced soil volume and the construction of the cap. Consequently, short-term impacts on the community and remedial workers for Alternative 6 are slightly less than those discussed for Alternative 3.

Environmental Impacts

Potential environmental impacts of Alternative 6 onsite activities are similar to Alternative 3 (Section 5.2.3.5), with exceptions discussed below.

Geology and Soils. In the downtown area, a large volume of soil would be excavated at SLDS. The excavated areas would be backfilled with soil having lower levels of radionuclides, recontoured, and revegetated or paved to control surface water runoff.

Borrow material needed for backfill would be obtained from offsite sources and procured as a commodity in accordance with government procurement regulations in effect at the time of the remedial action. Potential borrow material sources that can meet the expected demands can be found in the St. Louis area. Some ecological impacts may be experienced at the borrow site location to inhabitants of the ecosystem.

Standard mitigative measures by the operators would be used to reduce the potential for erosion during construction and operation at the disposal facility. Good engineering practices by the disposal operation would also be used to reduce the potential for water erosion, and mitigative measures would be used as needed.

In the absence of an accident, transportation of the waste would have little effect on offsite soil. Contingency plans would be in place to address spills, so if an accident occurred that resulted in the release of contaminated material, the spill area would be cleaned up promptly; thus, no long-term effects are expected.

Water Quality/Resources. For onsite activities, this alternative would affect water quality in the same manner as for Alternative 3. Alternative 6, like Alternatives 3, 4, and 5, would have a short-term negative effect on surface water quality due to surface runoff. Treatment of groundwater from dewatering of extracted soil will serve to alleviate the localized groundwater contamination conditions. The proposed monitoring plan, the reliability, and availability of environmental monitoring are described in Section 5.2.

Existing regulations for operation of disposal facilities would be protective of groundwater and surface water at the disposal facility.

Adverse effects on surface water or groundwater related to transportation are unlikely except in the event of an accident. If an accidental release occurred, it would be cleaned up in accordance with the contingency plan, to prevent potential movement of contaminated material to any nearby water body.

Biotic Resources. The short-term effects during soil excavation would produce the same slightly negative effect at SLDS for Alternative 6 as described for Alternative 3.

Impacts to biota at the commercial borrow soil location(s) cannot be assessed since this commodity will be procured from an unknown source at the time of remedial action.

At the disposal facility, some wildlife in the vicinity of the site could be temporarily affected by noise, human activity, and fugitive dust associated with construction of the disposal cell, transport of the waste to the site, and placement of the waste into the cell. Potential impacts from fugitive dust emissions would be minimized through the implementation of dust control measures during construction and transportation activities.

Threatened and Endangered Species. The effects of Alternative 6 activities on threatened and endangered species are the same as those for Alternatives 3, 4, and 5.

Wetlands Impacts. Alternative 6 is not expected to have any impact on wetlands.

Floodplains Impacts. The effects of Alternative 6 onsite activities on the floodplain are the same as those for Alternatives 3, 4, and 5 because work is being performed in the same floodplain area for these alternatives.

No floodplain impacts are expected at disposal facilities. Existing regulations governing such facilities and specific provisions of a disposal facility's permit are expected to mitigate any potential impacts of disposal on floodplains.

Air Quality. The effects of Alternative 6 onsite activities on air quality are similar to those described for Alternatives 3, 4, and 5. Impacts on offsite air quality during disposal transportation and disposal are expected to be negligible.

Archaeological, Historical, and Cultural Resources

The effects of implementing Alternative 6 are similar to Alternatives 3, 4, and 5. Excavations are unlikely to affect cultural resources. This alternative would not affect any known archaeological resources other than those already addressed in Alternative 3.

Disposal facility operations are unlikely to disturb historical, archeological or cultural resources by accepting these wastes.

Land Use and Recreational/Aesthetic Resources

The effect on land use from implementing Alternative 6 would be similar to Alternative 3 except that restrictions on digging would be maintained in some areas.

Because existing disposal sites would receive the waste, no significant effects will occur on land use as a result of offsite disposal.

Socioeconomic and Institutional Issues

Community and Institutional Issues. Community and institutional issues for Alternative 6 onsite activities are similar to Alternative 4 (Section 5.2.3.5). However, a wider range of future uses for the properties are possible due to the greater depth of excavation using the more stringent criteria. Short-term impacts in the form of annoyance, inconvenience, and disruption of activities would occur during excavation and transportation activities. Coordination would be undertaken to minimize disruption to the extent possible.

Public Services. Public services are similar to those described under Alternative 3 (Section 5.2.3.5). Additional coordination would be done to ensure that emergency response channels and facilities are available for the maximum credible emergency that may occur.

Transportation Impacts. The principal effects on local road transportation and traffic are similar to those indicated in Alternative 3.

Unavoidable Adverse Impacts and Mitigative Measures

Short-term environmental effects during implementation of Alternative 6 onsite activities are similar to those described for Alternative 3. Adverse activities and impacts associated with disposal would involve transportation to and handling at the disposal site. Operational plans, contingency plans, and mitigative cleanup measures would be developed to address mishaps en route or at the disposal location. Land use at the disposal site would be restricted.

Short-Term Uses and Long-Term Productivity

The short-term and long-term effects associated with Alternative 6 include comparable loss of small animal habitat in excavation areas and increased noise, traffic, and dust during site remedial activities similar to Alternative 3. Current uses would be re-established at the conclusion of remedial activities. Future uses would be enhanced by the reduction in digging restrictions imposed.

Cumulative Impacts

Rail and heavy equipment activity associated with the movement of excavated soils to an offsite disposal facility would incrementally increase local traffic volumes and noise. This incremental impact would be temporary in nature, ceasing with the completion of remedial activities. Air quality would be incrementally affected by exhaust emissions of traffic, and additional fugitive dust would result from the activities. These cumulative impacts would be temporary in nature and would cease with completion of remedial activities.

5.2.6.6 Implementability

Construction and operation of the removal and disposal components of Alternative 6 would be straightforward. The majority of the activities requiring implementation for Alternative 6 are comparable to those for Alternative 3 (ie, institutional controls, soil excavation, truck transport of soil, and environmental monitoring). Readily available resources and standard procedures are available for waste disposal. The implementability of the disposal options are straightforward processes involving common technologies.

The implementability of the offsite disposal option component of Alternative 6 would also depend on the implementability of bulk transport of the waste to the offsite location. The use of railroads to haul bulk material (ie, coal, dirt, rock) is a common practice. Some special handling of the contaminated soil would be required but should be straightforward and readily implementable. State and federal regulations would need to be addressed, and licenses, permits, and administrative procedures would need to be in place before transport and disposal could take place.

Offsite transport of the contaminated material to the disposal site would consist of either truck transport from SLDS to the disposal site or transfer of the material to rail cars and rail transport to the low-level waste disposal facility. Equipment, facilities, and the required personnel for truck and rail transport are readily available. The waste would be shipped in standard gondolas.

SLDS has several existing sidings, and the railroad owner could potentially assist in locating a siding that could be used for staging and loading. Construction and operation of a rail siding, if needed, would be straightforward. Material staging and loading would be accomplished with standard, industry-proven technologies.

The substantive requirements for a permit for the construction and operation of the rail siding would be met. Information pertinent to shipment of the SLDS waste (eg, waste characteristics and emergency handling information) would be entered into the railroad computer system for access by the railroad emergency response teams, if needed. A spill contingency plan would be developed and, in the event of a spill, an emergency response team would reload the spilled material into containers, test the area for residual contamination, and remediate the area, as needed. Transport of the waste offsite would require significant coordination among agencies. All shipments would be required to meet applicable federal regulations.

The administrative feasibility of Alternative 6 would be impacted for the offsite disposal options by the requirements for coordinating offsite transport and disposal. Numerous federal regulations, licenses, permits, and administrative procedures would need to be addressed before transport and disposal could take place. These requirements might impact the time required to implement this alternative.

5.2.6.7 Cost

The total capital cost of this alternative includes excavation of all soils above criteria, transportation, and disposal of contaminated soils and sediments. The total 30-year cost of this alternative, which is dependent on the disposal option selected, is estimated to be \$114 million (Appendix B). The cost difference between Alternative 6 and the cost of not implementing any remedial action per Alternative 1 is estimated at \$ 92 million (Appendix B). Long-term onsite environmental monitoring program constitutes most of the O&M cost for this alternative. The O&M environmental monitoring costs are from initiation of the remediation phase through completion of the post-closure confirmatory process. Supporting information is provided in Appendix B. As with the other excavation alternatives, inaccessible soil was included in the cost estimate.

An additional cost estimate was performed for Alternative 6 to evaluate the cost savings that could be realized by using overburden below composite criteria as backfill from the 4-6 foot depth to grade. If the material below composite criteria is reused as backfill in the interval from 4-6 foot to grade, the cost of remediation is reduced to \$98 million.

5.3 COMPARATIVE ANALYSIS OF SITE-WIDE ALTERNATIVES

Site-wide alternatives undergo comparative analysis for the purpose of identifying relative advantages and disadvantages of retained alternatives on the basis of the previous detailed analysis. The comparative analysis provides a means by which remedial alternatives can be directly compared to one another with respect to common criteria. Overall protection and compliance with ARARs are threshold criteria that must be met by an alternative for it to be eligible for selection. The other five criteria, consisting of short- and long-term effectiveness; reduction of contaminant volume, toxicity, and mobility through treatment; ease of implementation; and cost are the primary balancing criteria used to select a preferred remedy among alternatives satisfying threshold criteria. The community and state acceptance criteria are intended to be addressed after the public comment period and, therefore, are not included in this report. Table 5-3 summarizes the results of the comparative analysis of the seven criteria for the five alternatives. Table 5-4 summarizes the comparison of the environmental consequences for the five alternatives.

5.3.1 Overall Protection of Human Health and the Environment

Each of the alternatives, except No Action (Alternative 1), is protective of human health and the environment. The degree of protection and permanence of the protectiveness is a function of whether and to what extent an alternative uses dedicated engineering containment, a removal strategy, or land use and institutional control strategies.

The No Action alternative cannot be implemented at SLDS because it would not achieve the threshold criteria of being protective of human health and the environment as required by the NCP. It is included in the FS to provide a baseline case. Alternative 2 would use institutional controls to achieve overall protection of human health and the environment from soil and groundwater contamination. Alternatives 3, 4, 5 and 6 would use engineered and institutional controls to achieve overall protection of human health and the environment from soil and groundwater contamination.

Under Alternative 5, contaminated materials will be ultimately excavated and disposed with the result that institutional controls will be removed. Alternatives 2, 3, 4, 5, and 6 will reduce the long-term risks associated with existing contamination to protective levels.

The comparative analysis indicates the following relationships:

- the risk of construction worker related accidents and fatalities is greatest for Alternative 3, somewhat less for Alternative 5 due to not constructing an onsite cap, less still for Alternatives 4 and 6 due to the reduced volume of excavation, and least for Alternative 2.

- the transportation of St. Louis waste long distances from the site involves risk of injuries and fatalities that are much greater than any radiological cancer incidence resulting from transport;

- the risk of worker and public transportation fatality increases from Alternative 2, 3, 4, 6 to 5 due to increasing excavated contaminated soil volume and approved backfill volume;

- the risk of a traffic accident or fatality is greater for truck transport than for rail transport given the same hauling distance; and

- the projected number of traffic accidents and fatalities is greater for members of the public than for members of the transportation crew for a given scenario.

Table 5-3. Summary of Comparative Analysis of Site-Wide Alternatives

Criteria	Alternative 1 No Action	Alternative 2 Institutional Controls/ Site Maintenance	Alternative 3 Consolidation and Capping	Alternative 4 Partial Excavation and Disposal	Alternative 5 Complete Excavation and Disposal	Alternative 6 -Selective Excavation and Disposal
Overall Protection						
• Human Health	Not Protective	Protective as long as proposed institutional controls are maintained in perpetuity	Similar to Alternative 2, but risk is less if institutional controls fail because contaminated area is consolidated.	Protective	Protective	Protective
• Groundwater	Not Protective	Prevents consumption by deed restrictions and drilling restrictions	Similar to Alternative 2, but risk is less if institutional controls fail because contaminated area is consolidated.	Protective	Protective	Protective
• Environment	Not Protective	Protective	Protective	Protective	Protective	Protective
Compliance with ARARs	Not compliant for soils	Compliant as long as proposed institutional controls are maintained	Compliant; supplemental standards and institutional controls invoked for inaccessible soils and capped area. Backfill would need to pass hazardous characterization	Compliant; supplemental standards and institutional controls invoked for inaccessible soils until remediated. Backfill would need to pass hazardous characterization	Compliant; supplemental standards and institutional controls invoked for inaccessible soils until remediated. Backfill would need to pass hazardous characterization	Compliant; supplemental standards and institutional controls invoked for inaccessible soils until remediated. Soil would need to pass hazardous characterization before use as fill.
Long-term Effectiveness and Permanence						
• Magnitude of Remaining Risk	Same as BRA	Low as long as proposed institutional controls are maintained	Low as long as proposed institutional controls are maintained; lower than Alternative 2 if controls fail.	Low	Low	Low
• Adequacy of Controls	Existing site security would provide limited control over exposure	Adequate as long as proposed institutional controls are maintained	Good	Good	Excellent	Good
• Reliability of Controls	Limited by need for security	Reliable for security as long as institutional controls are maintained	Reliable for security as long as institutional controls are maintained. Better than Alternative 2 because area to be controlled is consolidated.	Reliable	Reliable	Reliable

Table 5-3. Summary of Comparative Analysis of Site-Wide Alternatives (continued)

Criteria	Alternative 1 No Action	Alternative 2 Institutional Controls/ Site Maintenance	Alternative 3 Consolidation and Capping	Alternative 4 Partial Excavation and Disposal	Alternative 5 Complete Excavation and Disposal	Alternative 6 -Selective Excavation and Disposal
• Long Term Management	Long-term management plan; environmental monitoring; site security	Long-term management plan; environmental monitoring; site security	Long-term management plan; environmental monitoring; site security	Long-term management plan; environmental monitoring; site security; radiological restrictions may be reduced following remedy selection for inaccessible soils	Long-term management plan environmental monitoring; site security; only necessary until remedy for inaccessible soils is selected.	Long-term management plan; environmental monitoring; site security; radiological restrictions may be reduced following selection of remedy for inaccessible soils
• Irreversible and Irretrievable Commitment of Resources	Restricted land use	Restricted land use	Restricted land use at capped area; fill material; petroleum	Restricted land use at disposal facility; restricted to confined industrial use; fill material; petroleum	Restricted land use at disposal facility; fill material; petroleum	Restricted land use at disposal facility; restricted to confined industrial use; fill material; petroleum
Reduction of Contaminant (overall)						
• Volume	None	None	None, however, treatment retained as a conditional part of the remedy	Onsite volume greatly reduced with offsite disposal options; however, treatment retained as a conditional part of the remedy.	Onsite volume eliminated with offsite disposal options; however, treatment retained as a conditional part of the remedy.	Onsite volume reduced due to offsite disposal; however, treatment retained as a conditional part of the remedy.
• Toxicity	None	None	None	None	None	None
• Mobility	None	None	Reduced by the cap component of disposal	Reduced by removal component	Eliminated by removal component	Reduced by removal component
Short-term Effectiveness and Environmental Impacts						
• Protection of Community	No additional health effect	Protective with controls	Minimal short-term risk to community; protective with controls; long-term benefit	Minimal short-term risk to community; protective with controls; long-term benefit	Minimal short-term risk to community; protective with controls; long-term benefit	Minimal short-term risk to community; protective with controls; long-term benefit
• Protection of Workers	No additional health effect	Protective with controls	Short-term occupational risk to workers; protective with controls	Short-term occupational risk to workers; protective with controls	Short-term occupational risk to workers; protective with controls, which may be discontinued following removal of inaccessible soil.	Short-term, occupational risk to workers; protective with controls

Table 5-3. Summary of Comparative Analysis of Site-Wide Alternatives (continued)

Criteria	Alternative 1 No Action	Alternative 2 Institutional Controls/ Site Maintenance	Alternative 3 Consolidation and Capping	Alternative 4 Partial Excavation and Disposal	Alternative 5 Complete Excavation and Disposal	Alternative 6 -Selective Excavation and Disposal
• Environmental Impacts						
– Geology and Soils	Potential uncontrolled migration of contaminants	Potential uncontrolled migration of contaminants	Short-term soil disturbance during excavation; replacement of soil	Short-term soil disturbance during excavation; replacement of soil	Short-term soil disturbance during excavation; replacement of soil	Short-term, soil disturbance during excavation; replacement of soil
– Water Quality	No adverse effects beyond baseline conditions	No adverse effects beyond baseline conditions	Short-term minor impacts during excavation; short-term impact on surface water; long-term improvement in surface and groundwater	Short-term minor impacts during excavation; short-term impact on surface water; long-term improvement in surface and groundwater	Short-term minor impacts during excavation; short-term impact on surface water; long-term improvement in surface and groundwater	Short-term minor impacts during excavation; short-term impact on surface water; long-term improvement in surface and groundwater
– Biotic Resources						
Terrestrial biota	No adverse effect beyond baseline conditions	No adverse effect beyond baseline conditions	Temporary loss of habitat; long-term benefits due to removal of contaminant source; permanent loss of habitat for disposal location	Temporary loss of habitat; long-term benefits due to removal of contaminant source	Temporary loss of habitat; long-term benefits due to removal of contaminant source	Temporary loss of habitat; long-term benefits due to removal of contaminant source
Aquatic biota	No adverse effect beyond baseline conditions	No adverse effect beyond baseline conditions	Minimal adverse effect during excavation	Minimal adverse effect during excavation	Minimal adverse effect during excavation	Minimal adverse effect during excavation
– Threatened and Endangered Species	No impact	No impact	No impact	No impact	No impact	No impact
– Wetlands	No wetlands present	No wetlands present	No wetlands present	No wetlands present	No wetlands present	No wetlands present
– Floodplains	No impact	No impact	Potential impact over long-term if levee fails	No impact over long-term	No impact over long-term	No impact over long term
– Air Quality	No impact	Improvement with radon controls	Short-term increase in fugitive dust associated with remediation activities; improvement with radon controls	Short-term increase in fugitive dust associated with remediation activities; improvement with radon controls	Short-term increase in fugitive dust associated with remediation activities; improvement with radon controls	Short-term increase in fugitive dust associated with remediation activities; improvement with radon controls
• Archeological, Cultural, and Historical Resources	No impact	No impact	No impact	No impact	No impact	No impact
• Land Use and Recreational/Aesthetic Resources	Land use continues but future reuse is limited	Land use continues but future reuse is restricted by institutional controls	Restricted land use for inaccessible soils and capped area; restrictions on groundwater use; unrestricted land use for remediated areas	Restricted land use; restrictions on groundwater use and land use	Restricted land and groundwater use for inaccessible soils; unrestricted land use for remediated areas	Restricted land use; reduced restrictions compared to Alternative 4 due to greater depth of excavation; restrictions on groundwater use

Table 5-3. Summary of Comparative Analysis of Site-Wide Alternatives (continued)

Criteria	Alternative 1 No Action	Alternative 2 Institutional Controls/ Site Maintenance	Alternative 3 Consolidation and Capping	Alternative 4 Partial Excavation and Disposal	Alternative 5 Complete Excavation and Disposal	Alternative 6 -Selective Excavation and Disposal
• Socioeconomic and Institutional Issues						
– Community and Institutional Issues	Conflict with community. Inhibits land use.	Conflict with community. Inhibits land use.	Near term impact on community. Allows development outside of capped area. Impact on industrial properties.	Near term impact on community. Allows development to proceed. Impact on industrial properties.	Near term impact on community. Allows development to proceed. Impact on industrial properties until inaccessible soil remediated.	Near term impact on community. Allows development to proceed. Less impact on industrial properties than Alternative 4.
– Public Services	No impact on utilities. Low potential for impact on emergency response services.	No impact on utilities. Low potential for impact on emergency response services.	Low impact on utilities. Short-term potential impact on emergency response services.	Low impact on utilities. Short-term potential impact on emergency response services.	Low impact on utilities. Short-term potential impact on emergency response services.	Low impact on utilities. Short-term potential impact on emergency response services.
– Local Transportation Impacts	No impact	No impact	Minor local traffic volume increased and road deterioration during implementation	Moderate local traffic volume increased and road deterioration during implementation	Significant local traffic volume increased and road deterioration during implementation	Moderate local traffic volume increased and road deterioration during implementation
• Unavoidable Adverse Impacts	Potential risks to human health and the environment posed by site-related contaminants	All contaminants remain onsite requiring institutional controls	Potential short-term negative impact on surface water and air quality; short-term loss of habitats and animals; potential increase in noise annoyance, fugitive dust and traffic volume	Potential short-term negative impact on surface water and air quality; short-term loss of habitats and animals; potential increase in noise annoyance, fugitive dust and traffic volume	Potential short-term negative impact on surface water and air quality; short-term loss of habitats and animals; potential increase in noise annoyance, fugitive dust and traffic volume	Potential short-term negative impact on surface water and air quality; short-term loss of habitats and animals; potential increase in noise annoyance, fugitive dust and traffic volume
• Short-term Uses and Long-term Productivity	Short-term use remains; long-term productivity would decline with limited reuse of land	Short-term use remains; long-term productivity would decline with restricted reuse of land	Short-term use influenced by remedial activities; long-term productivity high for unrestricted areas; cap reduces long-term productivity by restricting future land use	Short-term use influenced by remedial activities; long-term productivity high for unrestricted areas; reduced long-term productivity by restricting future land use	Short-term use influenced by remedial activities; long-term productivity high for unrestricted areas; restricted at disposal facility	Short-term use influenced by remedial activities; long-term productivity high for unrestricted areas;long-term productivity enhanced over Alternative 4
• Cumulative Impacts	None	None	Ongoing activities at Mallinckrodt Inc. in relation to inaccessible soils. Loss of use of capped area.	Ongoing activities at Mallinckrodt Inc. in relation to inaccessible soils	Ongoing activities at Mallinckrodt Inc. in relation to inaccessible soils	Ongoing activities at Mallinckrodt Inc. in relation to inaccessible soils

Table 5-3. Summary of Comparative Analysis of Site-Wide Alternatives (continued)

Criteria	Alternative 1 No Action	Alternative 2 Institutional Controls/ Site Maintenance	Alternative 3 Consolidation and Capping	Alternative 4 Partial Excavation and Disposal	Alternative 5 Complete Excavation and Disposal	Alternative 6 -Selective Excavation and Disposal
IMPLEMENTABILITY						
• Technical Feasibility	Feasible	Feasible	Feasible	Feasible	Feasible	Feasible
• Administrative Feasibility	Feasible	Feasible but requiring institutional controls such as rezoning and deed restrictions	Feasible but requires institutional controls such as rezoning, land purchases deed restrictions.	Feasible but requires institutional controls such as rezoning and deed restrictions.	Feasible but requires institutional controls until remedy for inaccessible soils is selected.	Feasible but requires institutional controls such as rezoning and deed restrictions.
• Monitoring	Long-term onsite monitoring	Long-term onsite monitoring	Long-term onsite monitoring	Long-term monitoring at disposal facility and at locations of inaccessible soils	Long-term monitoring at disposal facility and at locations of inaccessible soils	Long-term monitoring at disposal facility and at locations of inaccessible soils
COST						
• Total Cost	$22 million	$29 million	$100 million	$92 in million	$140 million (overburden reused) $170 millon (overburden to off-site disposal)	$98 million (overburden reused) $114 million (overburden to off-site disposal)

Table 5-4. Comparison of Environmental Consequences

	Alternative 1 No Action	Alternative 2 Institutional Controls/ Site Maintenance	Alternative 3 Consolidation and Capping	Alternative 4 Partial Excavation and Disposal	Alternative 5 Complete Excavation and Disposal	Alternative 6 - Selective Excavation and Disposal
Geology and Soils	The baseline case leaves 92,000 m^3 (120,000 yd^3) of contaminated soil left in place. Contaminant migration would be unaffected.	No additional impacts above baseline. Impacts of baseline case mitigated using institutional controls.	Short-term disturbance during excavation and replacement of soil; Inaccessible soils controlled using institutional controls until remedy is selected; good engineering practices and mitigative measures would be utilized during remedial.	Short-term disturbance during excavation and replacement of soil; Inaccessible soils controlled using institutional controls; until remedy is selected; good engineering practices and mitigative measures would be utilized during remedial action and at the disposal site.	Short-term disturbance during excavation and replacement of soil; Inaccessible soils controlled using institutional controls until remedy is selected; good engineering practices and mitigative measures would be utilized during remedial action and at the disposal site.	Short-term disturbance during excavation and replacement of soil; Inaccessible soils controlled using institutional controls; until remedy is selected; good engineering practices and mitigative measures would be utilized during remedial action and at the disposal site.
Water Quality	The baseline case leaves groundwater in contact with above ALARA criteria soils ; long-term monitoring required.	Impacts of baseline case mitigated using institutional controls.	Short-term minor impacts in surface water quality during excavation; long-term improvement in surface water and groundwater quality; contamination isolated from precipitation; long-term groundwater monitoring required.	Short-term minor impacts in surface water quality during excavation; long-term improvements in surface water and groundwater quality; long-term groundwater monitoring required until remedy is selected for inaccessible soils; reduction in contaminant concentration and volume would have favorable impacts on groundwater.	Short-term minor impacts in surface water quality during excavation; long-term improvements in surface water and groundwater quality; long-term groundwater monitoring required until remedy for inaccessible soils is selected; reduction in contaminant concentration and volume would have favorable impacts on groundwater	Short-term minor impacts in surface water quality during excavation; long-term improvements in surface water and groundwater quality; long-term groundwater monitoring required until remedy for inaccessible soils is selected; reduction in contaminant concentration and volume would have favorable impacts on groundwater.
Air Quality	The baseline case leaves radon emissions uncontrolled; airborne impact would occur if uncontrolled excavation takes place.	Radon controls and excavation restrictions reduce concentrations to acceptable levels.	Short-term increase in fugitive dust emissions during excavation; radon controls reduce radon concentrations to acceptable levels.	Short-term increase in fugitive dust emissions during excavation; radon controls reduce radon concentrations to acceptable levels.	Short-term increase in fugitive dust emissions during excavation; radon controls reduce radon concentrations to acceptable levels.	Short-term increase in fugitive dust emissions during excavation; radon controls reduce radon concentrations to acceptable levels.
Biotic Resources						
• Terrestrial Biota	The baseline case has no current adverse effects occurring to biota; continued exposure of biota to contaminants could potentially create effects.	Exposure of biota to contaminants maintained at acceptable levels using institutional controls.	Temporary loss of habitat area at the city property; no further exposure after vegetation reestablishment; temporary loss of herbaceous vegetation and woody shrubs; long-term improvement resulting from consolidation of	Temporary loss of habitat area at the city property; no further exposure after vegetation reestablishment; temporary loss of herbaceous vegetation and woody shrubs; long-term improvement resulting from removal of contaminants.	Temporary loss of habitat area at the city property; no further exposure after vegetation reestablishment; temporary loss of herbaceous vegetation and woody shrubs; greater long-term improvement resulting from removal of contaminants.	Temporary loss of habitat area at the city property; no further exposure after vegetation reestablishment; temporary loss of herbaceous vegetation and woody shrubs; long-term improvement resulting from removal of contaminants.

Table 5-4. Comparison of Environmental Consequences (Continued)

	Alternative 1 No Action	Alternative 2 Institutional Controls/ Site Maintenance	Alternative 3 Consolidation and Capping	Alternative 4 Partial Excavation and Disposal	Alternative 5 Complete Excavation and Disposal	Alternative 6 - Selective Excavation and Disposal
• Aquatic Biota	The baseline case has no current adverse effects occurring to biota; continued exposure of biota to contaminants could potentially create effects.	Exposure of biota to contaminants maintained at acceptable levels using institutional controls.	Potential short-term impact from increased runoff during excavation.	Potential short-term impact from increased runoff during excavation.	Potential short-term impact from increased runoff during excavation.	Potential short-term impact from increased runoff during excavation.
Threatened and Endangered Species	The baseline case shows no impact.	No impact.	No impact.	No impact.	No impact.	No impact.
Wetlands and Floodplains	No impact.	No impact.	No wetlands present; floodplain could be impacted by capped area if levee fails.	No wetlands present; areas located in the 100-year floodplain would be impacted during excavation and construction; no impact to floodplains over long-term.	No wetlands present; areas located in the 100-year floodplain would be impacted during excavation and construction; no impact to floodplains over long-term.	No wetlands present; areas located in the 100-year floodplain would be impacted during excavation and construction; no impact to floodplains over long-term.
Archaeological, Cultural, and Historical Resources	The baseline case shows no impact on known resources.	No impact on known resources.	No impact on known resources.	No impact on known resources.	No impact on known resources.	No impact on known resources.
Land Use and Recreational/Aesthetic Resources	The baseline case would limit future development of properties due to contamination.	Future use of properties restricted by institutional controls.	Portions of site released from institutional controls as site is remediated; disposal site property lost for other uses; potential impact on surrounding property use and value; offsite land use effects from the purchase, extraction, and transport of fill materials.	Portions of site released from institutional controls as site is remediated; potential impact on surrounding property use and value; offsite land use effects from the purchase, extraction, and transport of fill materials; no new significant impact to land use for offsite disposal sites.	Portions of site released from institutional controls as site is remediated; potential impact on surrounding property use and value; offsite land use effects from the purchase, extraction, and transport of fill materials; no new significant impact to land use offsite disposal sites.	Portions of site released from institutional controls as site is remediated; restrictions less severe than Alternative 4 allowing continued development; potential impact on surrounding property use and value; offsite land use effects from the purchase, extraction, and transport of fill materials; no new significant impact to land use for offsite disposal sites.
Socioeconomic Issues						
• Community and Institutional Issues	The baseline case involves conflict with community.	Institutional controls used to address conflict with community development plans.	Contaminated soil being consolidated a concern; high impact upon stakeholder development plans.	Impact upon Stakeholder development plans.	Minimal impact with community development plans.	Minimal impact with community development plans.
• Public Services	The baseline case indicates no impact on utilities. Low potential for impact on emergency response services.	No impact on utilities. Low potential for impact on emergency response services.	Low impact on utilities. Short-term coverage needed from emergency response services.	Low impact on utilities. Short-term coverage needed from emergency response services.	Low impact on utilities. Short-term coverage needed from emergency response services.	Low impact on utilities. Short-term coverage needed from emergency response services.

Table 5-4. Comparison of Environmental Consequences (Continued)

	Alternative 1 No Action	Alternative 2 Institutional Controls/ Site Maintenance	Alternative 3 Consolidation and Capping	Alternative 4 Partial Excavation and Disposal	Alternative 5 Complete Excavation and Disposal	Alternative 6 - Selective Excavation and Disposal
• Transportation Impacts	The baseline case indicates no impact.	No impact.	Minor impact on traffic patterns; increase in traffic volumes due to soil transport; potential road deterioration; impact on transportation due to cleanup of roadways and railroads.	Moderate impact on traffic patterns; increase in traffic. volumes due to soil transport; potential road deterioration; impact on transportation due to cleanup of roadways and railroads.	Significant impact on traffic patterns; increase in traffic volumes due to soil transport; potential road deterioration; impact on transportation due to cleanup of roadways and railroads.	Moderate impact on traffic patterns; increase in traffic volumes due to soil transport; potential road deterioration; impact on transportation due to cleanup of roadways and railroads.
Unavoidable Adverse Impacts	The baseline case indicates potential exposure to contaminants by direct inhalation, direct contact and ingestion from human disturbance and natural processes.	All contaminant exposures would be controlled using institutional controls.	Short-term loss of habitat and an increase in surface water sediment loading during excavation activities. Also temporary increase in local traffic, fugitive dust, and ambient noise.	Short-term loss of habitat and an increase in surface water sediment loading during excavation activities. Also temporary increase in local traffic, fugitive dust, and ambient noise.	Short-term loss of habitat and an increase in surface water sediment loading during excavation activities. Also temporary increase in local traffic, fugitive dust, and ambient noise.	Short-term loss of habitat and an increase in surface water sediment loading during excavation activities. Also temporary increase in local traffic, fugitive dust, and ambient noise.
Short-Term Use and Long-Term Productivity	The baseline case involves restricted land use.	Land use restricted in accordance with institutional controls.	Use of land at inaccessible properties restricted; land use/productivity committed to capped area; long-term productivity enhanced once areas remediated.	Use of land at inaccessible properties restricted; land use/productivity limited to industrial; long-term productivity enhanced once areas remediated.	Use of land at inaccessible properties restricted land use/productivity not restricted; long-term productivity enhanced once areas remediated.	Use of land at inaccessible properties restricted; land use/productivity limited to industrial; long-term productivity enhanced once areas remediated.
Irreversible and Irretrievable Commitment of Resources	The baseline case indicates no impact.	No significant impact.	Impacted resources include backfill material and petroleum; restricted use of capped area.	Impacted resources include backfill material and petroleum; long-term commitment of land for offsite disposal.	Impacted resources include backfill material and petroleum; long-term commitment of land for offsite disposal.	Impacted resources include backfill material and petroleum; long-term commitment of land for offsite disposal.

For the excavation and construction workers, overall protectiveness is highest for Alternative 3 in that it provides the lowest non-radiological occupational risk of fatality (approximately 0.002) due to less movement and handling of soil. In comparison, the offsite disposal options of Alternatives 4, 5 and 6 pose a greater risk than with Alternative 3.

Protection of community and workers during transportation and time required to complete remedial actions are dependent on the disposal options. The related fatality incidence ranges from 0.013 to 0.086.

Alternatives 3, 4, 5, and 6 would reduce contaminant mobility as a component of disposal. Capping or encapsulation would prevent infiltration of precipitation through contaminated materials. It is expected that the potential for contaminant leaching would be greatly reduced over current conditions. Furthermore, capping or encapsulation would eliminate contaminant migration by means of wind erosion or surface runoff, and would prevent human exposure to the waste. Alternatives 3, 4, 5, and 6 provide the greatest degree of protection from residual risk because contaminated materials identified as posing potentially unacceptable risks to human health and the environment are ultimately removed from the site and permanently isolated in an engineered disposal facility. All current potential exposure pathways are eliminated by these alternatives.

Alternative 1 does not control groundwater use. Alternative 2 restricts the use of groundwater through use of institutional controls. Alternatives 3, 4, 5, and 6 remove the source of potential future groundwater contamination from below the water table. Alternative 2 is more effective than Alternative 1 in controlling access to contamination. Alternatives 3, 4, 5, and 6 are as effective as Alternative 2 in controlling access to groundwater contamination and are more effective than Alternatives 1 and 2 at minimizing potential for future groundwater contamination and are comparable to each other in this regard.

Alternative 1 is the least protective because it leaves all contaminated media in place. Alternative 2 is more protective because, although the contaminated media is left in place, it still is protective as a result of institutional controls and site maintenance. Alternative 3 is more protective than Alternative 2 because it consolidates the soils in a central location thus reducing the opportunity for exposure. Alternative 4 is more protective than Alternative 3 because it removes the highest risk soil from the site. Alternative 6 is more protective than Alternative 4 because it removes contamination at lower concentrations to a greater depth than Alternative 4. Alternative 5 is the most protective because it removes the most contaminated soil from the site. Each alternative relies on continued institutional controls to maintain protectiveness, at least in areas with inaccessible soil.

5.3.2 Compliance with ARARs

Alternative 1 would not comply with ARARs, since radionuclide concentrations in readily accessible soil would continue to exceed guidelines. Alternative 2 would meet ARARs through implementation of institutional controls. Alternatives 3, 4, 5, and 6 would comply with ARARs. The substantive requirements for supplemental standards under 40 CFR 192 would be invoked for groundwater and inaccessible soils (while left in place) under Alternatives 3, 4, 5, and 6, and for Alternatives 4 and 6, for soil below the depth of excavation to 40 CFR 192 criteria. Thus, Alternatives 3, 4, 5, and 6 would achieve ARARs with supplemental standards being considered relevant and appropriate for inaccessible soils at the site until a remedy is determined. Supplemental standards are applicable when it can be demonstrated that remedial action would cause environmental harm that is excessive compared to health benefits, where remedial action would pose a clear and present risk of injury to workers, or where cleanup costs are unusually high and contamination left in place presents no significant exposure hazard. Restrictions on groundwater use due to MED/AEC material would cease in areas where the source term was remediated and protection of human health and the environment is determined by risk assessment. Accordingly, these alternatives would comply with relevant standards for restoration of radiologically contaminated sites. Appendix A contains a full listing of ARARs.

5.3.3 Long-Term Effectiveness and Permanence

Alternative 5 has the highest degree of long-term effectiveness and permanence because all contaminated soils are excavated for permanent disposal. Alternative 6 has the second highest degree of long-term effectiveness and permanence because the criteria used for excavation below the 4 to 6 ft depth are higher. Alternative 4 is third because the higher concentration criteria begin at a depth of 2 ft. Alternatives 4, 5, and 6 rely more on engineering controls and less on institutional controls for isolating contamination from the environment. Alternatives 3, 4, 5, and 6 have a high degree of long-term effectiveness and permanence compared to Alternatives 1 and 2 in terms of residual risk because contaminated soils are either permanently disposed of onsite or are transported offsite for permanent disposal. The cap for onsite disposal under Alternative 3 provides isolation of contamination from the environment. Alternatives 3, 4, and 6 rely more on institutional controls and less on engineering controls, therefore making these alternatives less effective long-term than Alternative 5. Alternative 2 has only a moderate degree of long-term effectiveness and permanence compared to Alternative 1 due to the contaminated soils and building materials remaining in place onsite and the primary use of institutional controls. Alternative 1, no action, has low long-term effectiveness and permanence.

Pursuant to SARA, a long-term management plan including five year reviews for all alternatives because some radioactive contaminants (ie, soil and/or groundwater) would remain onsite. By using institutional controls and groundwater monitoring, Alternatives 2, 3, 4, 5, and 6 would achieve comparable long-term effectiveness and permanence for groundwater quality.

Implementing Alternatives 2 or 3 would result in the permanent commitment of land for waste disposal. This commitment would occur throughout the downtown area for Alternative 2, and at Plant 2 or the city property for Alternative 3.

The Alternative 3 onsite cap would cover most of the Plant 2 area. A portion of the perimeter would need to be used as a buffer zone and the sides of the cap would be sloped to promote drainage. No other area of the St. Louis site would sustain a long-term impact as a result of this cleanup action. Perpetual care may be needed for the committed land because the waste would retain its toxicity for thousands of years. Thus, the cap would need to be visually inspected, groundwater would be monitored, and the effectiveness of the overall system would be reviewed every five years under Alternative 3.

Implementing any of the final action alternatives would not be constrained by the availability of resources or supplies beyond those currently available in the St. Louis area or expected to be available at the offsite disposal facilities. Consumptive use of geological resources (eg, quarried rock, sand, and gravel) and petroleum products (eg, diesel fuel and gasoline) would be required for the removal, construction, and disposal activities for Alternatives 3, 4, 5, and 6. Adequate supplies of these materials are readily available in the St. Louis area and would also be available in the area of the offsite disposal sites. Additional fuel use would result from offsite transport of the waste. However, adequate supplies are available without affecting local requirements for these products.

5.3.4 Reduction in Contaminant Volume, Toxicity, and Mobility through Treatment

At this time, treatment is a conditional component of the retained remedial alternatives. Even though Alternatives 1 through 6 offer no reduction in contaminant volume, toxicity, or mobility through treatment, the addition of treatment (if warranted in the future) could be achieved as an adjunct for Alternatives 3, 4, 5, or 6.

Alternatives 3, 4, 5, and 6 would reduce contaminant mobility by disposal. The disposal of the soils under the cap in Alternative 3 would reduce the migration of contaminants by retarding infiltration into contaminated soil, by preventing fugitive dust emissions, and by isolating surface runoff from the contaminated media. Offsite disposal for Alternatives 4, 5, and 6 would reduce onsite contaminant volume because contaminated materials would be permanently disposed of offsite.

5.3.5 Short-Term Effectiveness

An increase in the complexity of an alternative typically results in a decrease in short-term effectiveness because of increased waste handling and processing. Compared to Alternative 1, Alternative 2 is the most effective in protecting the community and workers from short-term impacts and in achieving implementation because there is no handling nor removal of waste materials. Alternative 2 requires the shortest time to implement, followed by Alternative 3. Alternatives 4 and 6 would have significantly greater short-term impact than Alternatives 1, 2, or 3 because contaminated soils would be shipped offsite, constraining the excavation rate. Alternative 5 has the longest implementation time frame. Alternatives 2, 3, 4, 5, and 6 are comparable in short-term effectiveness of groundwater contamination control.

With respect to soil excavation, Alternative 3 has a higher degree of short-term effectiveness compared to the other excavation alternatives, because it requires the minimum amount of handling or movement of the contaminated soils among the action alternatives. Once the soils are removed and incorporated into the area to be capped, an initial layer of fill material is deposited on the contaminated materials. An initial layer of fill material deposited on the contaminated materials would isolate the workers from the source material during remedial activities. Dust generated by the earth-moving aspects of the alternative would be controlled.

Alternatives 4, 5, and 6 offer a moderate degree of short-term effectiveness compared to Alternative 3 because they would require more time to implement than Alternative 3. The non-radiological occupational hazards increase significantly for Alternatives 4 and 5. Fugitive dust generation and increased erosion and silt loading of surface waters are among the most significant concerns of Alternatives 4, 5, and 6.

5.3.6 Implementability

The design, engineering, and administrative requirements of Alternatives 1 and 2 are essentially negligible. Materials required for the components of these alternatives are readily available. The remaining alternatives are all technically and administratively feasible. The engineering, design, and administrative requirements increase with the complexity of the alternatives in the following order: 4, 5, 6, and 3. Alternative 3 has the greatest complexity because of the construction of the cap in addition to excavation. Except for Alternatives 1 and 2, Alternative 4 is the most amenable to timely implementation of an expedited remedial approach. It requires the least site preparation, provides disposal (without construction of a disposal facility) of a smaller volume than Alternatives 5 or 6, and involves the least logistical problems. Alternative 5 is the next best approach to implementing expedited soil removal. It is less implementable than Alternative 4 because of the increased volume. Alternatives 4 and 6 would require segregating soil below the ALARA criteria and returning this material to depths. Alternative 3 would remove the same volume of soil as Alternative 5, but the additional task of design and construction of the liner and cap would delay implementation of Alternative 3 relative to Alternatives 4, 5, and 6.

Materials and services for the removal of contamination and environmental monitoring activities for the various alternatives are readily available. The degree of difficulty in implementing alternatives increases with the amount of contaminated soils to be excavated, the level of the design/transportation required to dispose of soils in accordance with regulations, and the time/coordination involved in completing the alternative.

5.3.7 Cost

The comparative analysis of costs compares the differences in capital, O&M, and present worth values. Costs for each alternative, itemization of individual components, and the sensitivity analysis for each alternative may be found in Appendix B. The total costs for the alternatives increase as follows: Alternative 1, 2, 3, 4, 6, and 5. The total 30-year cost for the five alternatives are:

Alternative 1 – No Action	$22 million
Alternative 2 – Institution Controls and Site Maintenance	$29 million
Alternative 3 – Consolidation and Capping	$100 million
Alternative 4 – Partial Excavation and Disposal	$92 million
Alternative 5 – Complete Excavation and Disposal	$140 million
Alternative 6 – Selective Excavation and Disposal	$114 million

The differences in costs among alternatives are very significant and increase primarily with the amount of contaminated soil to be excavated.

5.4 CONCLUSION

The selection of a preferred alternative is not presented in this FS report for the SLDS. The comparative analysis of the site-wide alternatives discussed in Section 5.3 provides information for use in selecting the preferred alternative. The selection of a final remedy will be influenced by public/agency review and comment on this FS.

The preferred alternative selected by USACE will be described in the Proposed Plan. In accordance with EPA guidance and regulations, the Proposed Plan will be released to the public for review and comment. Public input is paramount in the selection process. The preferred remedy may be modified based on the comments received. The response to public comment on the FS and the proposed plan and the final selected remedy will be documented in a ROD approved by EPA.

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APPENDIX A

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

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CHEMICAL SPECIFIC ARARS FOR THE SLDS

Standard, Requirement, Criteria or Limitation	Citation	Description of Requirement	ARAR Status	Comment
NRC Radiological Criteria for License Termination	10 CFR 20 Subpart E	This rule provides consistent standards to NRC licensees for determining the extent to which lands must be remediated before decommissioning of a site can be considered complete and the license terminated. These standards are: unrestricted use – 25 mrem/yr TEDE and ALARA; restricted use – 25 mrem/yr TEDE, ALARA, durable institutional controls, license termination plan (LTP), public input, and 100 mrem/yr or 500 mrem/yr if institutional controls fail; and alternate criteria – 100 mrem/y, ALARA, LTP, and EPA and public input.	Relevant and Appropriate	
Uranium Mill Tailings Radiation Control Act (UMTRCA) (October 1992): Cleanup of Radioactively Contaminated Land and Contaminated Buildings	40 CFR Sections 192.12(A), 192.32(B)(2), and 192.41(A)(B)(C)	Residual radioactive material concentration of Ra-226 and Ra-228 in land averaged over any 100 m^2 area shall not exceed the background level by >5 pCi/g averaged over the first 15 cm of soil (6 inches) and 15 pCi/g averaged over 15 cm thick layers of soil >15 cm below the surface.	Relevant and Appropriate	These requirements are relevant and appropriate based on the NCP evaluation factors of purpose (control of residual radioactive material), medium (contaminated soil), substance (uranium and thorium by-product materials), action/activity (cleanup standards and provisions), variances/waivers/exemptions (supplemental standards for difficult-to-access contaminated soils), and type of place (land and buildings contaminated with residual radioactive materials from inactive uranium processing). Note: Since 40 CFR 192 has been published, a more recent federal guidance has been developed which provides for averaging over survey units with areas different from 100 m^2.
Uranium Mill Tailings Radiation Control Act (UMTRCA) (October 1992)	40 CFR Section 192.02(A)	Addresses releases of radon from tailings piles	Relevant and Appropriate	Relevant and appropriate to those aspects of the remedial alternative which involve waste disposal. Describes requirements of waste disposal facilities.
UMTRCA: Supplemental Standards	40 CFR 192.20 - 192.22	Defines supplemental standards for application to difficult-to-access contaminated soils left in place under the remedial action alternative because these soils pose no significant current risk and future exposures would be controlled by institutional controls. Remedial action will generally not be necessary where residual radioactive materials have been placed semi-permanently in a location where site-specific factors limit their hazard and from which they are costly or difficult to remove, or where only minor quantities of residual radioactive materials are involved.	Relevant and Appropriate	May be relevant and appropriate for soils left in place in inaccessible or deep areas at SLDS.

Standard, Requirement, Criteria or Limitation	Citation	Description of Requirement	ARAR Status	Comment
Clean Water Act - Effluent Limitations for Discharge of Radioactive Pollutants to Surface Waters	40 CFR 440.32(b) and 40 CFR 440.34(a)	Provides that discharge of pollutants from mines as liquid effluent must meet the following limits: <10 pCi/L of dissolved Ra-226 in any one day or <3 pCi/L of dissolved Ra-226 averaged over 30 consecutive days; <30 pCi/L of total Ra-226 in any one day or ,10 pCi/L of total Ra-226 averaged over 30 consecutive days; and 4 mg/L of uranium in any one day or 2 mg/L of uranium averaged over 30 consecutive days.	Relevant and Appropriate	These limits reflect best practicable control technology (BPT) controls for pollutants in mine drainage from uranium, radium and vanadium ore mines. They can be used as guidelines for amounts of radioactivity allowed to be discharged into surface water or groundwater.
Primary Drinking Water Standards (MCLs for Radionuclides)	10 CSR 60-4.060	This rule provides that the MCL for radium-226 and radium-228 shall be: – combined Ra-226 and Ra-228, 5 pCi/l; – gross alpha particle activity including Ra-226 but excluding radon and uranium = 15 pCi/l.	Relevant and Appropriate	

APPENDIX B

ST. LOUIS DOWNTOWN SITE FS COST ANALYSIS INFORMATION

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B.1 INTRODUCTION

This appendix provides information regarding the cost estimate for the detailed analysis of alternatives for the St. Louis Downtown Site FS. These costs are not intended to provide a construction estimate for the remedial actions. The costs used in this analysis are based on Means Heavy Construction Cost Data (Means 1996), vendor quotes, and engineering estimates. Productivity adjustments are incorporated to compensate for lost productivity due to construction delays and safety requirements imposed due to impacted soil. These cost estimates are expected to provide an accuracy of -30 percent to +50 percent and are prepared using data available from the RI. The detail used to develop these costs should provide much more certainty (±20 percent) if the assumptions prove accurate.

These cost estimates should be used only for the FS detailed analysis of alternatives. Legal costs, siting studies, treatability testing, and the documentation of environmental impacts, including the public review process, could affect the cost estimates presented in this FS. The actual costs for these actions may be higher than estimated due to the large uncertainty in administrative costs and potential delays in implementing the action. Additionally, many costs are based on unproven treatment technologies or non-negotiated transportation costs and could vary widely. The maximum total expenditure has not been established for this project.

Format for the cost estimate is based on guidance from EPA documents. Section B.2 provides general cost information. This section includes information on the scope of the estimates, the Work Breakdown Structure (WBS), the Project schedules, the estimating methodology, the assumptions and key parameters, and an explanation of the direct and indirect capital costs and the operation and maintenance costs. Section B.3 includes the total 1998 costs for each alternative. Section B.4 presents a sensitivity analysis to show the effect that changes in key parameters and assumptions could have on total estimated cost.

B.2 GENERAL COST INFORMATION

B.2.1 ESTIMATE SCOPE

Scope is defined by the WBS elements for which costs have been estimated for each alternative. Costs are estimated for all WBS elements listed in Section B.2.2 except for WBS 1.1.1, Project Screening and Assessment and WBS 1.2, Discovery and Designation. Those elements are not included as they represent costs which are largely expended and thus, are considered sunk. Costs are estimated over a 30-year span for each alternative.

B.2.2 WORK BREAKDOWN STRUCTURE

The SAIC FUSRAP Work Breakdown Structure (WBS), June 6, 1994 was used as a basis to develop the St. Louis WBS (see Appendix Table B-1). The WBS is designed to subdivide the St. Louis Project into logical elements for cost estimating and to incorporate the project into the overall FUSRAP Program.

B.2.3 PROJECT SCHEDULE

Remediation activities could continue indefinitely for certain alternatives, however, major activities are typically complete within 20 to 30 years. For this reason, and to make the task of estimating feasible, all estimates are based on a 30-year project life cycle. Also, schedules for major construction activities are assumed to be constant and do not change between alternatives. This assumption also facilitates cost comparisons between alternatives. Specific schedules are calculated or based on engineering judgment.

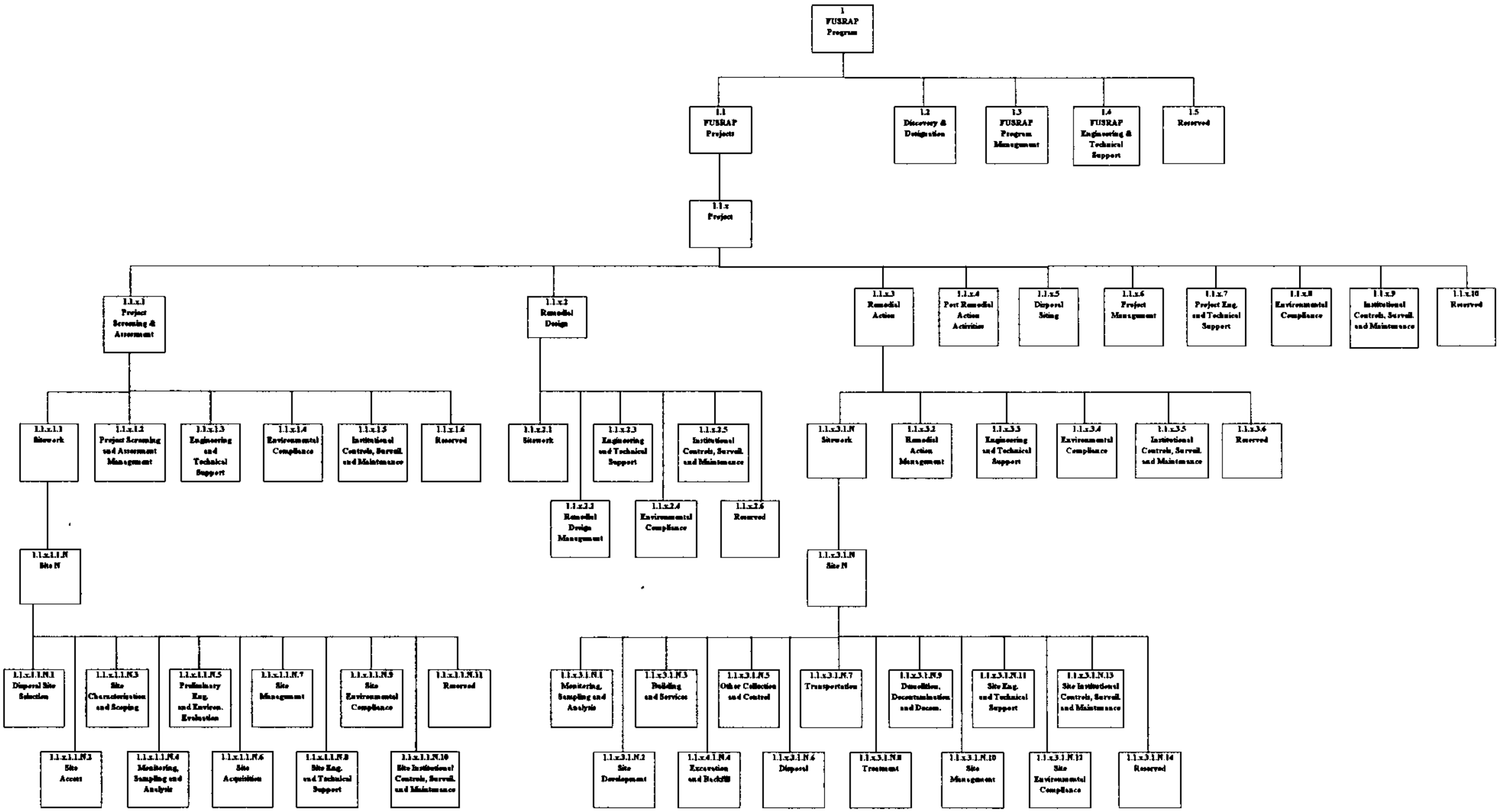
B.2.4 ESTIMATING METHODOLOGY

In general, FUSRAP cost estimates are generated for each of the activity-oriented WBS elements identified in Section B.2.2. However, due to the composition of the St. Louis Site, many WBS elements are further subdivided in order to provide further visibility and definition (e.g., subsurface, vicinity properties, etc.). Once estimated, costs are then "rolled up" from subordinate level WBS elements and summed to the parent level WBS element. Use of the WBS in this manner provides traceability from the total cost down to very specific estimate details.

The primary methodology utilized is of a quantity take-off nature whereby costs are calculated based on unit cost multiplied by quantity or other input parameters. Unit cost data used in the relationship is primarily drawn from the *Means Heavy Construction Cost Data (Means 1996).* An example of this is WBS 1.1.1.3.1.2, Site Development which is based on site requirements for ditches, rail spur renovation and other similar activities. Costs for this WBS are generated on a cost per quantity of labor and material. As another example, WBS 1.1.1.3.1.4, Excavation and Backfill is based on excavation volume as well as site specific complexities. This combination of volume and complexity in turn drives equipment, labor and material requirements.

Several WBS elements incorporate a productivity adjustment process as part of the estimating methodology. This process is accomplished through the use of factors which are applied to equipment performance measures in order to account for a degradation in the productivity, performance, or output levels of the equipment resulting from site-specific conditions. Productivity factors exist for three conditions: site, soil, and safety. Site adjustments are made to account for temporary work interruptions and delays resulting from poor weather, unsafe work conditions and other similar unforeseen events. Soil adjustments are made to account for varying levels of difficulty associated with excavating different types of soil or rubble. A safety adjustment is made to adjust

Table B-1. FUSRAP - WBS Summary



productivity levels due to safety procedures associated with the radioactive nature of impacted materials. Productivity adjustments are part of the methodology used to estimate costs for WBS 1.1.1.3.1.4 - Excavation and Backfill, and WBS 1.1.1.3.1.7 - Transportation (loading).

A contingency factor of 25 percent is applied to WBS element 1.1.1 - St. Louis FUSRAP Project (total project cost) at the bottom line. WBS element 1.3 - FUSRAP Program Management and Integration is calculated using a 10-percent factor based on WBS element 1.1.1 with contingency added.

In general, estimating methodology is not site- or alternative-specific. Once a methodology has been established for a given WBS element, it becomes the common methodology which is employed for that given WBS element across the various sites and alternatives.

B.2.5 KEY PARAMETERS, GROUNDRULES, AND ASSUMPTIONS

Key parameters are quantities, unit costs and assumptions which tend to drive the ultimate cost for a project. Key parameters for the St. Louis Downtown Site are shown in Table B-2 in 1998 dollars. Detailed estimates are developed in 1996 dollars and a factor is added to the overall estimate summary to convert it to 1998 dollars.

Groundrules and assumptions are statements of guidance and/or logic which are established in order to bound or limit the cost estimate. They serve to define the estimate by clarifying the effort which the estimate addresses and how cost for that effort is derived. Listed below are groundrules and assumptions which are common to all alternatives estimated for the St. Louis Downtown Site. Groundrules and assumptions are either WBS element-specific or site-specific and, as such, are not included here for the sake of document brevity. The following established statements for common groundrules and assumptions for the St. Louis Downtown Site are listed below.

- No sunk costs.
- All costs are reported in Base Year 1998 dollars in thousands unless otherwise noted.
- Escalation indices used are as reported in DOE-OR (FSRD) letter dated February 10, 1994; Subject: FY 1995 Unified Budget Call.
- Subcontractor material costs include a 10-percent material handling overhead (Means).
- Subcontractor labor costs include a 57-percent overhead (Means).
- Contingency factor of 25 percent is applied to WBS element 1.1.1 - St. Louis FUSRAP Project (total project cost) at the bottom line.
- WBS element 1.3 - FUSRAP Program Management and Integration is calculated using a 10-percent factor based on WBS element 1.1.1 with contingency added.

Table B-2
ST. LOUIS SITE KEY PARAMETERS
Alt. 1. No Action

PARAMETER	MALLINCKRODT	VICINITY PROPERTIES	BUILDINGS
Excavation Volume, Total (insitu cy)	0	0	0
Excavation Volume, Total (exsitu cy)	0	0	0
Clean soil from treatment (exsitu cy)	0	0	0
Demo / Decon Volume, Total (insitu cy)	0	0	0
Demo / Decon Volume, Total (exsitu cy)	0	0	0
Demo / Decon Weight, Total (tons)	0	0	0
Expansion Factor, Soil	1.25	1.25	1.25
Expansion Factor, Asphalt / Concrete	1.25	1.25	1.25
Expansion Factor, Rubble	1.25	1.25	1.25
Density, Soil (tons/insitu cy)	1.6	1.6	1.6
Density, Asphalt / Concrete (tons/insitu cy)	2.1	2.1	2.1
Density, Rubble (tons/insitu cy)	2.1	2.1	2.1
Soil Disposal Volume, Total (cy)	0	0	0
Debris Disposal Volume, Total (cy)	0	0	0
Disposal / Transport Volume (cy)	0	0	0
Soil Disposal Fee, Commercial ($/cy)	$ 149.00	$ 149.00	$ 149.00
Debris Disposal Fee, Commercial ($/cy)	$ 542.13	$ 542.13	$ 542.13
Loading Rate ($/cy)	$ 27.00	$ 27.00	$ 27.00
Gondola Transportation Rate ($/ton)	$ 73.00	$ 73.00	$ 73.00
Intermodal Transportation Rate ($/ton)	$ -	$ -	$ -
Gondola Transportation %	100%	100%	100%
Intermodal Transportation %	0%	0%	0%
Available construction weeks per year	44	44	44

All Costs in $FY98

Table B-2 (continued)

ST. LOUIS SITE KEY PARAMETERS

Alt. 2. Institutional Controls and Site Maintenance

PARAMETER	MALLINCKRODT	VICINITY PROPERTIES	BUILDINGS
Excavation Volume, Total (insitu cy)	0	0	0
Excavation Volume, Total (exsitu cy)	0	0	0
Clean soil from treatment (exsitu cy)	0	0	0
Demo / Decon Volume, Total (insitu cy)	0	0	0
Demo / Decon Volume, Total (exsitu cy)	0	0	0
Demo / Decon Weight, Total (tons)	0	0	0
Expansion Factor, Soil	1.25	1.25	1.25
Expansion Factor, Asphalt / Concrete	1.25	1.25	1.25
Expansion Factor, Rubble	1.25	1.25	1.25
Density, Soil (tons/insitu cy)	1.6	1.6	1.6
Density, Asphalt / Concrete (tons/insitu cy)	2.1	2.1	2.1
Density, Rubble (tons/insitu cy)	2.1	2.1	2.1
Soil Disposal Volume, Total (cy)	0	0	0
Debris Disposal Volume, Total (cy)	0	0	0
Disposal / Transport Volume (cy)	0	0	0
Soil Disposal Fee, Commercial ($/cy)*	$ 149.00	$ 149.00	$ 149.00
Debris Disposal Fee, Commercial ($/cy)	$ 542.13	$ 542.13	$ 542.13
Loading Rate ($/cy)	$ 27.00	$ 27.00	$ 27.00
Gondola Transportation Rate ($/ton)	$ 73.00	$ 73.00	$ 73.00
Intermodal Transportation Rate ($/ton)	$ -	$ -	$ -
Gondola Transportation %	100%	100%	100%
Intermodal Transportation %	0%	0%	0%
Available construction weeks per year	44	44	44

All Costs in $FY98

Table B-2 (continued)

ST. LOUIS SITE KEY PARAMETERS

Alt.3 Excavation, Consolidation and Capping

PARAMETER	MALLINCKRODT	VICINITY PROPERTIES	BUILDINGS
Soils Volume (Impacted)	53,231	9,873	0
Inaccessible Soils Volume (Impacted)	18,280	4,570	0
Deep Soils Volume (Impacted)	24,081	715	0
Inaccessible 'Deep Soils' Volume (Impacted)	9,450	0	0
Overburden	47,180	7,226	0
Total Accessible Volume (Impacted)	77,312	10,588	0
Total Inaccessible Volume (Impacted)	27,730	4,570	0
Total Volume (Impacted)	105,042	15,158	0
Accessible Volume (insitu cy)	139,954	19,932	0
Inaccessible Volume (insitu cy)	33,276	5,484	0
Excavation Volume, Total (insitu cy)	173,230	25,416	0
Excavation Volume, Total (exsitu cy)	216,538	31,770	0
Clean soil from treatment (exsitu cy)	0	0	0
Demo / Decon Volume, Total (insitu cy)	0	0	0
Demo / Decon Volume, Total (exsitu cy)	0	0	0
Demo / Decon Weight, Total (tons)	0	0	0
Expansion Factor, Soil	1.25	1.25	1.25
Expansion Factor, Asphalt / Concrete	1.25	1.25	1.25
Expansion Factor, Rubble	1.25	1.25	1.25
Density, Soil (tons/insitu cy)	1.6	1.6	1.6
Density, Asphalt / Concrete (tons/insitu cy)	2.1	2.1	2.1
Density, Rubble (tons/insitu cy)	2.1	2.1	2.1
Soil Disposal Volume, Total (cy)	157,563	22,737	0
Debris Disposal Volume, Total (cy)	0	0	0
Cell Waste Volume, Total (insitu cy)	0	0	0
Adjusted Cell Waste Volume, Total (insitu cy)	0	0	0
Soil Disposal Fee, Commercial ($/cy)*	$ 149.00	$ 149.00	$ 149.00
Loading Rate ($/cy)	$ 27.00	$ 27.00	$ 27.00
Gondola Transportation Rate ($/ton)	$ 73.00	$ 73.00	$ 73.00
Intermodal Transportation Rate ($/ton)	$ 143.00	$ 143.00	$ 143.00
Gondola Transportation %	100%	100%	100%
Intermodal Transportation %	0%	0%	0%
Available construction weeks per year	44	44	44

All Costs in $FY98

Table B-2 (continued)

ST. LOUIS SITE KEY PARAMETERS

Alt.4D Partial Excavation and Disposal

PARAMETER	MALLINCKRODT	VICINITY PROPERTIES	BUILDINGS
Accessible Soils Volume (Impacted insitu cy)	32,127	6,120	-
Accessible 'Deep Soils' Volume (Impacted insitu cy)	6,587	66	-
Inaccessible Soils Volume (Impacted insitu cy)	10,111	4,112	
Inaccessible 'Deep Soils' Volume (Impacted insitu cy)	2,874	-	
Overburden	14,499	780	-
Total Accessible Soils Volume (Impacted insitu cy)	38,714	6,186	
Total Inaccessible Soils Volume (Impacted insitu cy)	12,985	4,112	
Total Volume Addressed (Impacted insitu cy)	51,699	10,298	-
Excavation Volume, Total (insitu cy)	76,538	13,138	-
Excavation Volume, Total (exsitu cy)	95,672	16,422	-
Below Criteria Overburden used as Backfill (exsitu)	18,124	975	
Clean soil from treatment (exsitu cy)	0	0	0
Demo / Decon Volume, Total (insitu cy)	0	0	0
Demo / Decon Volume, Total (exsitu cy)	0	0	0
Demo / Decon Weight, Total (Tons)	0	0	0
Expansion Factor, Soil	1.25	1.25	1.25
Expansion Factor, Asphalt / Concrete	1.25	1.25	1.25
Expansion Factor, Rubble	1.25	1.25	1.25
Density, Soil (tons/insitu cy)	1.6	1.6	1.6
Density, Asphalt / Concrete (tons/insitu cy)	2.1	2.1	2.1
Density, Rubble (tons/insitu cy)	2.1	2.1	2.1
Soil Disposal Volume, Total (cy)	77,549	15,447	0
Debris Disposal Volume, Total (cy)	0	0	0
Cell Waste Volume, Total (insitu cy)	0	0	0
Adjustment Factor	1.05	1.05	1.05
Adjusted Cell Waste Volume, Total (insitu cy)	0	0	0
Soil Disposal Fee, Commercial ($/cy)	$ 149.00	$ 149.00	$ 149.00
Loading Rate ($/cy)	$ 27.00	$ 27.00	$ 27.00
Gondola Transportation Rate ($/ton)	$ 73.00	$ 73.00	$ 73.00
Intermodal Transportation Rate ($/ton)	$ -	$ -	$ -
Gondola Transportation %	100%	100%	100%
Intermodal Transportation %	0%	0%	0%
Available construction weeks per year	44	44	44

Table B-2 (continued)

ST. LOUIS SITE KEY PARAMETERS

Alt.5 Complete Excavation and Disposal

PARAMETER	MALLINCKRODT	VICINITY PROPERTIES	BUILDINGS
Soils Volume (Impacted)	53,231	9,873	0
Inaccessible Soils Volume (Impacted)	18,280	4,570	0
Deep Soils Volume (Impacted)	24,081	715	0
Inaccessible 'Deep Soils' Volume (Impacted)	9,450	0	0
Overburden	47,180	7,226	0
Total Accessible Volume (Impacted)	77,312	10,588	0
Total Inaccessible Volume (Impacted)	27,730	4,570	0
Total Volume (impacted)	105,042	15,158	0
Accessible Volume (insitu cy)	139,954	19,932	0
Inaccessible Volume (insitu cy)	33,276	5,484	0
Excavation Volume, Total (insitu cy)	173,230	25,416	0
Excavation Volume, Total (exsitu cy)	216,538	31,770	0
Clean soil from treatment (exsitu cy)	0	0	0
Demo / Decon Volume, Total (insitu cy)	0	0	0
Demo / Decon Volume, Total (exsitu cy)	0	0	0
Demo / Decon Weight, Total (Tons)	0.00	0.00	0.00
Expansion Factor, Soil	1.25	1.25	1.25
Expansion Factor, Asphalt / Concrete	1.25	1.25	1.25
Expansion Factor, Rubble	1.3	1.3	1.3
Density, Soil (tons/insitu cy)	1.6	1.6	1.6
Density, Asphalt / Concrete (tons/insitu cy)	2.1	2.1	2.1
Density, Rubble (tons/insitu cy)	2	2	2
Soil Disposal Volume, Total (cy)	157,563	22,737	0
Debris Disposal Volume, Total (cy)	0	0	0
Cell Waste Volume, Total (insitu cy)	0	0	0
Adjusted Cell Waste Volume, Total (insitu cy)	0	0	0
Soil Disposal Fee, Commercial ($/cy)	$ 149.00	$ 149.00	$ 149.00
Loading Rate ($/cy)	$ 27.00	$ 27.00	$ 27.00
Gondola Transportation Rate ($/ton)	$ 73.00	$ 73.00	$ 73.00
Intermodal Transportation Rate ($/ton)	$ 143.00	$ 143.00	$ 143.00
Gondola Transportation %	100%	100%	100%
Intermodal Transportation %	0	0	0
Available construction weeks per year	44	44	44

Table B-2 (continued)

ST. LOUIS SITE KEY PARAMETERS

Alt.6 Selective Excavation and Disposal

PARAMETER	MALLINCKRODT	VICINITY PROPERTIES	BUILDINGS
Shallow impacted insitu soils between DOE 5400.5 & ALARA criteria	45,198	11,959	-
Shallow impacted insitu soils exceeding ALARA criteria	6,725	680	-
Total impacted insitu soils exceeding DOE criteria	**51,923**	**12,639**	**-**
Shallow soils less than DOE 5400.5 criteria requiring removal	23,320	5,596	-
Total shallow soil volume addressed	**75,243**	**18,235**	**-**
Shallow excavated insitu soils between DOE 5400.5 & ALARA criteria	54,238	14,351	-
Shallow excavated insitu soils exceeding ALARA criteria	8,070	816	-
Total excavated insitu soils exceeding DOE criteria	**62,308**	**15,167**	**-**
Shallow excavated insitu soils below DOE 5400.5 criteria requiring removal	23,320	5,596	-
Total shallow soil volume addressed	**85,628**	**20,763**	**-**
Shallow exsitu volume between DOE 5400.5 & ALARA criteria	67,797	17,939	-
Shallow exsitu volume exceeding ALARA criteria	10,088	1,020	-
Total shallow exsitu volume exceeding DOE criteria	**77,885**	**18,959**	**-**
Shallow exsitu volume requiring removal below DOE 5400.5 criteria	29,150	6,995	-
Total shallow exsitu volume addressed	**107,035**	**25,954**	**-**
Deep impacted insitu soils exceeding ALARA criteria	14,109	155	-
Deep soils less than ALARA criteria requiring removal	7,984	295	-
Total deep soil volume addressed	**22,093**	**450**	**-**
Deep excavated insitu soils exceeding ALARA criteria	16,931	186	-
Deep excavated insitu soils less than ALARA criteria requiring removal	7,984	295	-
Total excavated insitu volume addressed	**24,915**	**481**	**-**
Deep exsitu volume exceeding ALARA criteria	21,164	233	-
Deep exsitu volume less than ALARA criteria requiring removal	9,980	369	-
Total exsitu volume addressed	**31,144**	**601**	**-**
Shallow exsitu volume available as fill for ALARA deep soil excavation	67,797	17,939	-
Deep soil ALARA fill requirement	21,164	233	-
Excess Shallow exsitu volume to disposal	75,784	24,701	-
Shallow exsitu volume exceeding ALARA criteria to disposal	10,088	1,020	-
Deep exsitu volume exceeding ALARA criteria to disposal	21,164	233	-
Total exsitu disposal volume	**107,035**	**25,954**	**-**
Demo / Decon Volume, Total (insitu cy)	-	-	-
Demo / Decon Volume, Total (exsitu cy)	-	-	-
Demo / Decon Weight, Total (tons)	-	-	-
Expansion Factor, Soil	1.25	1.25	1.25
Expansion Factor, Asphalt / Concrete	1.25	1.25	1.25
Expansion Factor, Rubble	1.25	1.25	1.25
Density, Soil (tons/insitu cy)	1.6	1.6	1.6
Density, Asphalt / Concrete (tons/insitu cy)	2.1	2.1	2.1
Density, Rubble (tons/insitu cy)	2.1	2.1	2.1
Debris Disposal Volume, Total (cy)	-	-	-
Cell Waste Volume, Total (insitu cy)	-	-	-
Soil Disposal Fee, Commercial ($/cy)	$ 149.00	$ 149.00	$ 149.00
Loading Rate ($/cy)	$ 27.00	$ 27.00	$ 27.00
Gondola Transportation Rate ($/ton)	$ 73.00	$ 73.00	$ 73.00
Intermodal Transportation Rate ($/ton)	-	-	-
Gondola Transportation %	100%	100%	100%
Intermodal Transportation %	-	-	-
Available construction weeks per year	44	44	44

- Escalation factor from $95 to $96, $96 to $97, and $97 to $98 is 1.036.

- Data sources for key parameters include the Volume Register, Rev. 11 (BNI 1997), this Feasibility Study for the St. Louis Downtown Site, and engineering judgment.

- Source for equipment cost and output is Means unless otherwise cited.

- Productivity adjustments used in many elements for weather and other delays.

- Expansion factor for ex situ/in situ soil is 1.25. An additional 20% is added for expected overexcavation.

- PPE cost = $3.75 per labor hour (Source: Hazardous Waste Control by Richard Selg).

- Remedial action down time calculated based on 3 months of down time for every 9 months of working time.

- Disposal fees based on current negotiated rates from the waste disposal contractor.

B.2.6 COST ESTIMATION

Federal construction programs have traditionally distinguished between the capital and operations and maintenance (O&M) costs. The remedial action alternatives for the St. Louis Downtown Site FS consist of those activities required to prevent or mitigate the migration of waste into the environment. The remedial action may include activities considered to be O&M in situations where construction alone will not achieve the health and environmental protection criteria.

The remedial action will have a schedule with a defined completion date. The post-closure or O&M phase occurs after the completion of the remedial action and includes those activities necessary to confirm closure of the remedial action or the activities necessary to monitor and prevent migration of releases of hazardous waste into the environment for an indefinite period.

B.2.6.1 Capital Costs

Capital costs are those expenditures required to implement a remedial action and consist of both direct and indirect costs. Capital costs do not include the costs required to maintain or operate the action throughout its lifetime.

B.2.6.1.1 Direct Capital Costs

Direct capital costs include equipment, labor, and material necessary for implementing the remedial action. These typically include costs for:

- site development;
- building and services;
- excavation and backfill;
- other collection and control;
- disposal;
- transportation;
- treatment; and
- demolition, decontamination and decommissioning.

B.2.6.1.2 Indirect Capital Costs

Indirect capital costs consist of engineering, supervision, management, administration, financial and other services necessary to implement a remedial action. These costs are not incurred as part of actual remedial actions but are ancillary to direct or construction costs. Indirect costs typically include:

- remedial design;
- site and project management;
- site and project engineering and technical support;
- site and project environmental compliance;
- site and project institutional controls, surveillance and maintenance;
- program management and technical support.

B.2.6.2 Operations and Maintenance (O&M) Costs

Operation and maintenance costs are those post-remedial action costs necessary for monitoring and ensuring hazardous waste will not migrate into the environment. These costs typically include:

- monitoring, sampling and analysis;
- institutional controls;
- site management/engineering and technical support in support of O&M activities;
- program management and technical support in support of O&M activities.

B.3 REMEDIAL ACTION ALTERNATIVE COST SUMMARIES

Table B-3 provides a cost breakdown in fiscal year 1998 dollars by activity for each alternative.

B.4 SENSITIVITY ANALYSIS

A sensitivity analysis was conducted to assess the effects variations of key parameters will have on total estimated cost for specific alternatives. The key parameters selected are considered major cost drivers for the remediation since variations in these parameters will have the greatest impact on total cost. The results of the sensitivity analysis are presented in Table B-4.

Table B-3
St. Louis Downtown Site
FUSRAP Remediation Alternatives
30 Year Costs in Thousands of FY98$

ACTIVITY	ALT. 1 MALLINCKRODT 0 yd^3 *	ALT. 1 VICINITY PROPERTIES 0 yd^3 *	ALT. 1 BUILDINGS 0 yd^3 *	ALT. 1 TOTAL 0 yd^3 *
Excavation & Backfill	0	0	0	0
Transportation	0	0	0	0
Disposal	0	0	0	0
Monitoring, Sampling and Analysis	0	0	0	0
Site Development	0	0	0	0
Building & Services	0	0	0	0
Treatment	0	0	0	0
Demolition and Decontamination	0	0	0	0
Project Management & Engineering Support	0	0	0	0
Other Collection and Controls	0	0	0	0
Onsite Management and Engineering Support	0	0	0	0
Site Inst. Controls, Surveillance & Maint.	0	0	0	0
Remedial Design	0	0	0	0
Subtotal Project	**0**	**0**	**0**	**0**
Contingency	0	0	0	0
Program Management and Integration	0	0	0	0
Total Removal Action	**0**	**0**	**0**	**0**
Post Remedial Action O&M	8,579	7,990	5,086	21,654
Total 30 Year Cost	**8,579**	**7,990**	**5,086**	**21,654**

*Total Impacted Insitu Volume

Table B-3 (continued)

St. Louis Downtown Site
FUSRAP Remediation Alternatives
30 Year Costs in Thousands of FY98$

ACTIVITY	ALT. 2 MALLINCKRODT 0 cy^3 *	ALT. 2 VICINITY PROPERTIES 0 cy^3 *	ALT. 2 BUILDINGS 0 cy^3 *	TOTAL 0 cy^3 *
Excavation & Backfill	0	0	0	0
Transportation	0	0	0	0
Disposal	0	0	0	0
Monitoring, Sampling and Analysis	0	0	0	0
Site Development	0	0	0	0
Building & Services	0	0	0	0
Treatment	0	0	0	0
Demolition and Decontamination	0	0	0	0
Project Management & Engineering Support	0	0	0	0
Other Collection and Controls	0	0	0	0
Onsite Management and Engineering Support	0	0	0	0
Site Inst. Controls, Surveillance & Maint.	0	0	0	0
Remedial Design	0	0	0	0
Subtotal Project	0	0	0	0
Contingency	0	0	0	0
Program Management and Integration	0	0	0	0
Total Removal Action	0	0	0	0
Post Remedial Action O&M	12,113	11,524	5,080	28,718
Total 30 Year Cost	**12,113**	**11,524**	**5,080**	**28,718**

*Total Impacted Insitu Volume

Table B-3 (continued)
St. Louis Downtown Site
FUSRAP Remediation Alternatives
30 Year Costs in Thousands of FY98$

ACTIVITY	ALT. 3 MALLINCKRODT 105,042 yd3 *	ALT. 3 VICINITY PROPERTIES 15,158 yd3 *	ALT. 3 BUILDINGS 0 yd3 *	TOTAL 120,200 yd3 *
Excavation & Backfill	13,891	5,701	0	19,592
Transportation	5,015	827	0	5,842
Disposal	6,196	1,021	0	7,217
Monitoring, Sampling and Analysis	1,097	351	14	1,461
Site Development	585	491	1	1,077
Building & Services	339	320	14	674
Treatment	0	0	0	0
Demolition and Decontamination	0	0	251	251
Project Management & Engineering Support	864	864	864	2,593
Other Collection and Controls	1,810	248	0	2,058
Onsite Management and Engineering Support	2,942	1,923	418	5,284
Site Inst. Controls, Surveillance & Maint.	175	109	0	285
Remedial Design	2,084	914	70	3,068
Subtotal Project	**34,999**	**12,770**	**1,632**	**49,400**
Contingency	8,750	3,192	408	12,350
Program Management and Integration	4,375	1,596	204	6,175
Total Removal Action	**48,124**	**17,558**	**2,244**	**67,926**
Post Remedial Action O&M	16,071	11,279	4,879	32,230
Total 30 Year Cost	**64,195**	**28,837**	**7,123**	**100,155**

*Total Impacted Insitu Volume

Table B-3 (continued)

St. Louis Downtown Site

FUSRAP Remediation Alternatives

30 Year Costs in Thousands of FY98$

ACTIVITY	ALT. 4D MALLINCKRODT 51,699 yd^3 *	ALT. 4D VICINITY PROPERTIES 10,298 yd^3 *	ALT. 4D BUILDINGS 0 yd^3 *	TOTAL 61,997 yd^3 *
Excavation & Backfill	8,136	4,391	0	12,528
Transportation	9,350	1,862	0	11,212
Disposal	11,551	2,301	0	13,852
Monitoring, Sampling and Analysis	1,308	362	14	1,683
Site Development	585	491	1	1,077
Building & Services	312	302	14	628
Treatment	0	0	0	0
Demolition and Decontamination	0	0	251	251
Project Management & Engineering Support	440	440	440	1,319
Other Collection and Controls	0	0	0	0
Onsite Management and Engineering Support	1,497	972	418	2,888
Site Inst. Controls, Surveillance & Maint.	84	55	0	139
Remedial Design	1,192	657	70	1,919
Subtotal Project	**34,456**	**11,834**	**1,207**	**47,497**
Contingency	8,614	2,959	302	11,874
Program Management and Integration	4,307	1,479	151	5,937
Total Removal Action	**47,377**	**16,272**	**1,660**	**65,308**
Post Remedial Action O&M	10,910	10,789	4,980	26,679
Total 30 Year Cost	**58,287**	**27,061**	**6,640**	**91,987**

*Total Impacted Insitu Volume

Table B-3 (continued)
St. Louis Downtown Site
FUSRAP Remediation Alternatives
30 Year Costs in Thousands of FY98$

ACTIVITY	ALT. 5 MALLINCKRODT $105,042\ yd^3$ *	ALT. 5 VICINITY PROPERTIES $15,158\ yd^3$ *	ALT. 5 BUILDINGS $0\ yd^3$ *	TOTAL $120,200\ yd^3$ *
Excavation & Backfill	14,123	5,701	0	19,824
Transportation	18,997	2,741	0	21,739
Disposal	23,470	3,387	0	26,857
Monitoring, Sampling and Analysis	2,469	495	14	2,977
Site Development	585	491	1	1,077
Building & Services	329	310	14	652
Treatment	0	0	0	0
Demolition and Decontamination	0	0	251	251
Project Management & Engineering Support	699	699	699	2,098
Other Collection and Controls	0	0	0	0
Onsite Management and Engineering Support	2,381	1,361	418	4,161
Site Inst. Controls, Surveillance & Maint.	134	76	0	210
Remedial Design	2,002	843	70	2,915
Subtotal Project	**65,189**	**16,105**	**1,467**	**82,760**
Contingency	16,297	4,026	367	20,690
Program Management and Integration	8,149	2,013	183	10,345
Total Removal Action	**89,634**	**22,144**	**2,017**	**113,795**
Post Remedial Action O&M	10,690	10,620	4,918	26,229
Total 30 Year Cost	**100,325**	**32,764**	**6,935**	**140,024**

*Total Impacted Insitu Volume

Table B-3 (continued)

St. Louis Downtown Site

FUSRAP Remediation Alternatives

30 Year Costs in Thousands of FY98$

ACTIVITY	ALT. 6 MALLINCKRODT 89,352 yd^3 *	ALT. 6 VICINITY PROPERTIES 18,391 yd^3 *	ALT. 6 BUILDINGS 0 yd^3 *	TOTAL 107,743 yd^3 *
Excavation & Backfill	10,156	5,417	0	15,573
Transportation	12,905	3,129	0	16,034
Disposal	15,943	3,866	0	19,809
Monitoring, Sampling and Analysis	1,761	530	14	2,305
Site Development	585	491	1	1,077
Building & Services	323	308	14	645
Treatment	0	0	0	0
Demolition and Decontamination	0	0	251	251
Project Management & Engineering Support	617	617	617	1,850
Other Collection and Controls	0	0	0	0
Onsite Management and Engineering Support	2,099	1,263	418	3,781
Site Inst. Controls, Surveillance & Maint.	118	71	0	189
Remedial Design	1,504	808	70	2,382
Subtotal Project	**46,013**	**16,500**	**1,384**	**63,897**
Contingency	11,503	4,125	346	15,974
Program Management and Integration	5,752	2,062	173	7,987
Total Removal Action	**63,268**	**22,687**	**1,903**	**87,858**
Post Remedial Action O&M	10,761	10,696	4,938	26,395
Total 30 Year Cost	**74,028**	**33,383**	**6,841**	**114,253**

*Total Insitu Volume Addressed

Table B-4
Sensitivity Analysis - St. Louis Site
FUSRAP Remediation Alternatives

ALTERNATIVE	BASELINE COST	DISCOUNT FACTOR		TREATMENT PERFORMANCE		TREATMENT COST		SOIL VOLUME	
		5.0%	10.0%	62%	82%	50% INCREASE	50% DECREASE	20% INCREASE	20% DECREASE
NO ACTION, ALT. 1	$ 22	$ 11	$ 7	n/a	n/a	n/a	n/a	n/a	n/a
INSTITUTIONAL CONTROLS, SURVEILLANCE, AND MAINTENANCE, ALT. 2	$ 29	$ 20	$ 17	n/a	n/a	n/a	n/a	n/a	n/a
COMPLETE EXCAVATION, CONSOLIDATE AND CAP, ALT. 3	$ 100	$ 84	$ 72	n/a	n/a	n/a	n/a	$ 110	$ 90
PARTIAL EXCAVATION AND COMMERCIAL DISPOSAL, ALT. 4D	$ 92	$ 71	$ 59	n/a	n/a	n/a	n/a	$ 102	$ 82
COMPLETE EXCAVATION AND COMMERCIAL DISPOSAL, ALT. 5	$ 140	$ 115	$ 96	n/a	n/a	n/a	n/a	$ 160	$ 120
PARTIAL EXCAVATION, REUSE, AND COMMERCIAL DISPOSAL, ALT. 6	$ 114	$ 92	$ 77	n/a	n/a	n/a	n/a	129	100

St. Louis Downtown Site (SLDS) Project

FUSRAP Remediation Alternatives

Sensitivity Analysis

Percent Increase (Decrease)

ALTERNATIVE	BASELINE COST	DISCOUNT FACTOR		TREATMENT PERFORMANCE		TREATMENT COST		SOIL VOLUME	
		5.0%	10.0%	62%	82%	20% INCREASE	20% DECREASE	20% INCREASE	20% DECREASE
NO ACTION, ALT. 1	$ -	(47%)	(66%)	n/a	n/a	n/a	n/a	n/a	n/a
INSTITUTIONAL CONTROLS, SURVEILLANCE AND MAINTENANCE, ALT. 2	$ -	(29%)	(42%)	n/a	n/a	n/a	n/a	n/a	n/a
COMPLETE EXCAVATION, CONSOLIDATE AND CAP, ALT. 3	$ -	(16%)	(29%)	n/a	n/a	n/a	n/a	10%	(10%)
PARTIAL EXCAVATION AND COMMERCIAL DISPOSAL, ALT. 4D	$ -	(23%)	(36%)	n/a	n/a	n/a	n/a	11%	(11%)
COMPLETE EXCAVATION AND COMMERCIAL DISPOSAL, ALT. 5	$ -	(18%)	(31%)	n/a	n/a	n/a	n/a	14%	(14%)
PARTIAL EXCAVATION, REUSE, AND COMMERCIAL DISPOSAL, ALT. 6		(20%)	(33%)	n/a	n/a	n/a	n/a	13%	(12%)

APPENDIX C

SLDS ALARA ANALYSIS

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SLDS ALARA ANALYSIS

C.1 INTRODUCTION

Background

The U.S. Army Corps of Engineers (USACE) is currently working to clean up several sites in the St. Louis area which contain residual radioactive material as a result of former operations performed under contract with the United States government. These remedial actions are being performed by the Formerly Utilized Sites Remedial Action Program (FUSRAP). Congress established FUSRAP in 1974 under the authority of the Atomic Energy Act (AEA) of 1954 to identify, evaluate, and, if necessary, clean up former sites associated with Manhattan Engineer District (MED)-related radiological operations. In general, MED-related operations and subsequent related activities released radioactive residues to the soil at these sites at levels that do not allow release of the properties without radiological restrictions.

The St. Louis Downtown Site (SLDS) is located in an industrial area on the eastern border of St. Louis, is 90 m (300 ft) west of the Mississippi River, and 18 kilometers (km) [11 miles (mi) southeast of the St. Louis Airport Area. SLDS consists of the Mallinckrodt property and adjacent commercial and city owned properties, collectively referred to as the vicinity properties. A large chemical manufacturing and process facility owned and operated by Mallinckrodt, Inc., covers approximately 18 ha (45 acres) of the site, and contains many buildings that house Mallinckrodt offices and non-MED/AEC related chemical processing operations. From 1942 until 1957, Mallinckrodt, Inc., was contracted by the MED and AEC to process uranium ore for the production of uranium metal. The process involved the acid digestion of uranium. Residuals of the process, including spent pitchblende ore and process chemicals were inadvertently released from the Mallinckrodt facility into the environment through handling and disposal practices. These residuals had elevated levels of radioactive radium, thorium, and uranium.

SLDS is one of several St. Louis FUSRAP sites. The St. Louis site is comprised of a number of properties in the St. Louis area, including SLDS, the Ballfields, the St. Louis Airport Site (SLAPS), the SLAPS vicinity properties (VPs), the Latty Avenue VPs, and the Hazelwood interim storage site (HISS). This assessment evaluates several remediation (and cleanup guideline) options at SLDS to determine which option offers the greatest benefit in terms of reducing doses to as low as reasonably achievable (ALARA). As defined by the Nuclear Regulatory Commission (NRC), ALARA is a basic concept of radiation protection which specifies that exposure to ionizing radiation, and the control and releases of radioactive materials should be managed to reduce individual and collective doses (to both the work force and the general public) to as far below regulatory limits as is reasonably achievable considering economic, technological, and societal factors, among others. The ALARA process considers all potential sources of significant risk from remediation activities including non-radiological sources (eg, construction and transportation risk). As used in this assessment, ALARA is not a dose or risk limit, rather it is a process that has as its objective the attainment of dose and risk levels as far below applicable limits as practicable.

Relevant and appropriate regulations dealing with release of sites containing radioactivity can be found in 40 CFR 20 Subpart E, Radiological Criteria for License Termination. This rule includes criteria for license termination under unrestricted and restricted conditions. For unrestricted release, projected future doses must be less than 25 mrem/yr to a member of the critical group. If a license is terminated under restricted conditions, the licensee must make provisions for legally enforceable institutional controls that provide assurance that the total effective dose equivalent will not exceed 25 mrem/yr to the average member of the critical group, and if institutional controls fail, the dose will not exceed 100 mrem/yr. This rule also requires an ALARA analysis to show that doses are reduced to as low as practicable below the regulatory units.

C.1.2 SCOPE AND PURPOSE

The purpose of this ALARA analysis is to determine the most appropriate target radionuclide removal levels for the partial excavation alternative (Alternative 4) of the SLDS FS by considering the cost of remediation, radiological dose to site workers, and impacts to public and worker populations. This analysis is required by the NRC decommisioning rule as promulgated at 10 CFR 20 Subpart E. The analysis is consistent with guidance provided in the draft NUREG-1500 (*Working Draft Regulatory Guide on Release Criteria for Decommissioning: NRC Staff's Draft for Comment*) and NUREG-1496 (*Draft Generic Environmental Impact Statement in Support of Rulemaking on Radiological Criteria for Decommissioning*). The approach using the ALARA process to determine cleanup guidelines consists of three steps:

(1) characterization of contamination at SLDS;
(2) estimation of impacts and costs at residual dose levels; and
(3) assessment of ALARA based on a comparison of the incremental reductions in those impacts.

C.1.2.1 Step 1: Characterization

There have been four major characterization efforts at SLDS under the FUSRAP program. These include the 1977 designation survey by Oak Ridge National Laboratory (ORNL 1981), a radiological characterization by Bechtel National, Inc. (BNI 1990), and two data gap sampling efforts (SAIC 1995, and a separate boundary delineation effort in 1996 to support remediation work at Plant 2). Each investigation identified Ra-226, Th-230, and U-238 as the primary radiological contaminants. The 1977 and 1996 efforts also identified Pa-231 and Ac-227 as contaminants of concern (as does the Baseline Risk Assessment). Results from these characterization efforts indicate non-uniform concentrations of these primary radionuclides at SLDS and specifically in Plants 1, 2, 5, 6, and 7 (mostly uranium at Plant 2 while mostly radium at Plant 7). The ALARA analysis addresses the distribution of radionuclides present in baseline conditions and uses the site database to estimate residual concentrations of each radionuclide under each remediation scenario.

The site database used for this analysis consists of the data from the RI report (BNI 1990), and the RI addendum report (SAIC 1995). The data in this database is sufficient to complete an ALARA analysis. Therefore, Step 1 is considered complete (although additional characterization data may become available in the future). For a more detailed discussion and listing of site data, see the 1995 Remedial Investigation Addendum (SAIC 1995) or Section 2.3 of this Feasibility Study (FS).

C.1.2.2 Step 2: Impacts and Costs

The possible impacts estimated in Step 2 include:

1. Impacts to people on the site after remediation in the form of exposure to residual radioactivity in soil and groundwater,

2. Impacts to people working in remediated site buildings in the form of exposure to radioactivity on building surfaces,

3. Impacts to workers performing remediation activities and transporting waste to disposal facilities in the form of exposure to radioactivity,

4. Impacts to workers performing remediation activities and transporting waste to disposal facilities in the form of risk of death from construction activities and traffic accidents, and

5. Impacts to members of the public from exposure to residual radioactivity, radioactivity released during construction activities and transportation of waste, and traffic accidents during transportation to a disposal facility.

Some of these impacts contribute relatively insignificant sources of dose or risk to potential receptors. Although in some cases each of the impacts noted above may be an important piece of an ALARA analysis, only those impacts that could have an effect on decision making for cleanup at the SLDS property are considered here. As an example, groundwater ingestion is not considered in this evaluation since the SLDS is currently using water from a municipal supplier, and groundwater beneath the site is not considered a potential source of drinking water due to its poor quality (high iron, manganese, and total dissolved solids). Based on this approach, the following impacts are considered in this ALARA analysis:

- The dose to a site industrial worker exposed to residual radioactivity in soil,
- The dose to a remediation worker exposed to radioactivity in soil,
- The risk to a remediation worker from construction activities, and
- The risk to a worker or member of the public of having a fatal accident during waste transport.

Dose and risk calculations are discussed in more detail in Section 2 of this appendix.

The total cost associated with each remedial alternative is estimated by adding individual costs of excavations and backfill, loading and transportation of waste, disposal of waste, site controls (such as monitoring and surveillance, as appropriate), and program support and contingencies. Each cost estimate is directly related to the volume of material excavated. Volume estimates are provided using the site database and earthVision® software. The earthVision® software is used to provide three dimensional (3-D) models of site data. 3-D models are used for this ALARA analysis to provide the best estimate of site volumes (both residual and disposal volumes) for each remedial alternative at SLDS. Details associated with the cost estimates are provided in Appendix B of the FS.

C.1.2.3 Step 3: Assessment of ALARA

The general approach for determining ALARA used here is to compare the impact from each remedial alternative to the associated cost of remediation. Individual dose and collective dose are estimated. The individual dose is estimated for a member of each potential critical group including a site industrial worker and a remediation worker. Collective dose is estimated assuming the site is a rare metal extraction facility reused as an industrial facility (using guidance from the draft NUREG 1500 Appendix G Annex A). The building is assumed to cover 100,000 ft^2 (9,290 m^2) in area and have an occupancy of 100 persons. Because the contamination is not isolated to one location, it is assumed that there are 2 such buildings[1] bringing the total number of persons potentially exposed to 200. Because the risk of a traffic accident or construction-related accident are likely orders of magnitude higher than the risk of cancer from exposure to radioactivity at SLDS, radiation and non-radiation risks are not summed and non-radiation risks are not plotted versus cost or volume.

Construction related fatalities are estimated assuming a fatality rate of 4.2×10^{-8} fatalities per person-hour (NUREG/CR-1266). Fatalities caused by transportation of excavated soil and borrow for backfill are assumed to occur at a rate of 3.8×10^{-8} per mile (NUREG/CR-1266) for transport by truck or 4.52×10^{-8} per mile (Cashwell et al. 1989) for transport by train.

This ALARA analysis includes cost versus dose curves that can be used to visually identify possible cleanup limits. These curves along with other relevant cost, risk, and dose information will be used to determine cleanup limits for an industrial use risk-based alternative (Alternative 4) that are both protective to human health and cost effective.

C.2 ESTIMATION OF IMPACTS AND COSTS

C.2.1 DOSE AND RISK ASSESSMENT (IMPACTS)

The general approach for the dose/risk assessment follows guidelines established by EPA for conducting Baseline Risk Assessments *[Risk Assessment Guidance for Superfund, (RAGS) Volume 1 Human Health Evaluation Manual (Part A),* and *Part B, Development of Risk-based Preliminary Remediation Goals].* It also incorporates guidance for performing dose assessments from the NRC contained in NUREG/CR-5512 and PG-8-08 in terms of specific scenarios and exposure parameters recommended for a decommissioning assessment. Residual risks were calculated in accordance with USEPA CERCLA guidance using cancer risk slope factors from the November 1995 USEPA Health Effects Assessment Summary Tables (HEAST). Calculation of exposure concentrations utilized the

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[1] Note that a total of two buildings is a conservative estimate considering that these buildings would have to be located directly over the dispersed contaminated areas and post remediation footprints would likely total less than 200,000 ft^2 (18,600 m^2).

95% upper confidence limit of exposure unit mean concentrations above background pursuant to OSWER Directive 9200.4-18.

C.2.1.1 Exposure Setting

The SLDS has been owned and operated by Mallinckrodt for over 100 years. Mallinckrodt currently has no plans to abandon the site, and there is no indication that the site will revert to a non-industrial facility (eg, become residential). The area is highly industrialized and it is unlikely that the area would be anything but industrial in the foreseeable future. Under this assumption, two possible receptors (or groups of receptors) are considered to have a reasonable potential for exposure to radioactivity in site soils: a Mallinckrodt (industrial/construction) worker and a remediation worker.

Contamination at the site contains U-238, Th-230, Ra-226 (and associated decay products) and to a lesser extent Th-232, U-235, Pa-231 and Ac-227 (and associated decay products). Radionuclides are not, however, distributed homogeneously about the site and are present in varying stages of equilibrium. More precisely and based on available site data:

- The primary contaminant in the southwest corner of Plant 1 is Ra-226, but is limited to surface soil,
- The primary contaminant in the western portion of Plant 1 is Th-230,
- The primary contaminant in Plant 2 soil and in the southwest corner of Plant 6 is U-238,
- The primary contaminant in soil under the southeastern corner of Building 101 in Plant 6 and in the western portion of Plant 6 is Th-230, and
- The primary contaminant in soil under the former location of Building 700 in Plant 7 is Ra-226.

The site was broken into exposure units based on similar processes and radionuclide distributions. The six exposure units (one in Plant 1, one in Plant 2, three in Plant 6, and one in Plant 7) are shown in Figure C-1. The rationale for selecting these units is described in more detail in Section C.2.1.4.

Some of the most contaminated soil is present in shallow soil (top 2 ft), which for this assessment is assumed to be removed under all excavation alternatives (Alternatives 3, 4, 5, and 6) to the current composite cleanup criteria. Composite criteria combine the concentration limits for Ra-226 and Ra-228 found in 40 CFR 192 with the concentration limits for Th-230 and Th-232 found in DOE Order 5400.5. In addition, DOE Order 5400.5 provides for the derivation of limits for other radionuclides found at significant concentrations (U-238). These criteria are 5 pCi/g in the surface, or 15 pCi/g in the subsurface for Ra-226, Th-230, Ra-228, and Th-232. and 50 pCi/g for U-238 for soil in St. Louis at all depths. The contamination at any depth under the no removal alternatives

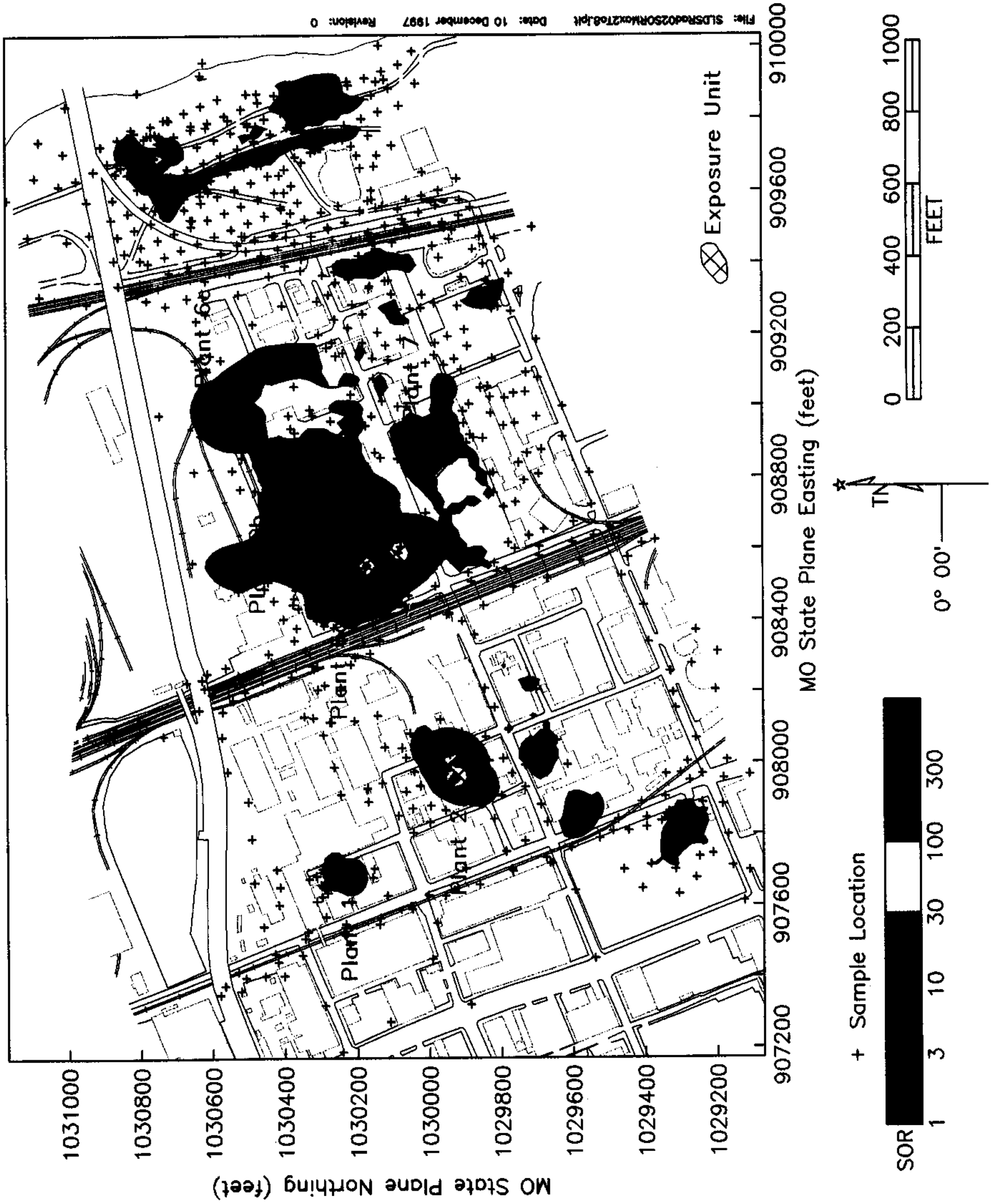

Figure C-1. SLDS ALARA Analysis Exposure Units (2 to 8 ft Interval)

(Alternatives 1 and 2) is assumed to be left undisturbed in place. For this ALARA analysis, the no action and complete removal alternative are used as bounding conditions.

The depth profile of contaminated soil varies by plant, and within each plant by building or area. For example, the contamination in Plant 1 is shallow in the southeast and deep in the northwest. Elevated concentrations of all primary radionuclides are known to exist in the top several feet of Plant 6 soil, but a pocket of mostly uranium contamination also exists starting at about eight feet under Building 100. It is conceivable that an individual can be exposed anywhere within the top eight feet of soil (eg, along utility corridors or during the installation of a building foundation). Exposure to soils deeper than eight feet in depth is considered unlikely, but is evaluated as part of this analysis.

C.2.1.2 Exposure Scenarios

Potential critical groups are defined below using site specific information and guidance provided in NUREG/CR-5512 (Residual Radioactive Contamination from Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Dose Equivalent) and PG-8-08 (Scenarios for Assessing Potential Doses Associated with Residual Radioactivity). Scenarios include a Mallinckrodt industrial/construction worker (a Mallinckrodt worker who works all year at the site and spends 400 hr/yr in construction/excavation activities), an industrial/utility worker [a Mallinckrodt worker who is involved in infrequent deep excavation (> 8 ft.) activities in addition to normal duties], and a remediation worker. A more detailed description of exposure parameters is included in Table C-1.

Industrial/Construction Worker

The site industrial/construction worker is on site for a standard work year (250 days) including 1600 hours indoors and 400 hours outdoors plus an additional 125 hours (0.5 hours per day) indoors to account for the possibility of eating lunch on site, early daily arrival, or late daily departure. The worker inhales an average of 1.2 m^3 of air per hour, ingests soil at a rate of 50 mg/day while indoors and 480 mg/day while outdoors (assuming construction excavation activity). The worker's physical description and exposure environment is based on a hybrid of the industrial and construction receptor models described in NUREG/CR-5512 and PG-8-08 guidance, where appropriate. The construction worker characteristics are added to the standard industrial receptor to emphasize (based on guidance from Mallinckrodt) the potential for site workers to routinely be in contact with bare soils. Exposure pathways include external gamma, dust inhalation, soil ingestion, and radon. The drinking water pathway is excluded since the SLDS uses water from a municipal supplier, and groundwater beneath the site is not considered a potential source of drinking water due to its poor quality.

Industrial/Utility Worker (Deep Excavation)

The industrial/utility worker is generally the same as the industrial/construction worker with one exception: he is involved in a deep excavation (> 8 ft.) somewhere on site where previously undisturbed elevated radionuclide concentrations remain. This is a one-time exposure that takes

Table C-1. Industrial/Construction and Remediation Worker Exposure Parameters

Parameter	Value [a]	Comment/Reference
Area of contaminated zone (m^2)	2,500	Maximum default area of contamination suggested by NUREG/CR-5512 and PG-8-08. Actual exposure units vary in size.
Inhalation rate (m^3/yr)	10,550	Conservative inhalation rate based on ICRP "light activity" values as an average for all indoor and outdoor activities used in NUREG/CR-5512 and PG-8-08. An 8.5 hour work day is assumed based on Mallinckrodt site-specific estimates.
Mass loading for inhalation (g/m^3)	0.0002	Mass loading for outdoor activities which gets adjusted by 0.5 shielding factor for indoor (industrial) exposure as per NUREG/CR-5512 and PG-8-08.
Fraction of time spent indoors	0.1969	Industrial/construction duration *indoors* assuming a total of 1,725 hours. This indoor occupancy included 1,600 hours plus an additional 125 hours (or 0.5 hours per day) also spent indoors on-site to account for lunch and other breaks (as recommended by Mallinckrodt based on site-specific information). The remediation worker is not assumed to be exposed indoors (fraction = 0.0).
Fraction of time spent outdoors	0.04566	Assuming 400 hours per year are spent *outdoors* (out of the total 2,125 hours available for the industrial/construction worker). The remediation worker outdoor exposure duration depends on the remedial option (A-F).
Indoor air exchange rate ($hour^{-1}$)	1.0	Assumes 1 exchange per hour for an industrial facility
Soil ingestion rate (g/yr)	49.64	Assuming 4/5th of time spent indoors with a soil ingestion rate of 50 mg/d (residential rate from NUREG/CR-5512 and PG-8-08) and 1/5th time outdoors with a rate of 480 mg/d (RAGS). Actual soil ingestion rates would be 10 g/yr indoors (over 200 days) and 24 g/yr outdoors (over 50 days), but rates are adjusted to account for a 365 day year (1/5th of year = 73 days, 4/5th = 292 days). This is necessary because RESRAD adjusts the total rate by an occupancy factor. The remedial worker ingestion rate is assumed to be 480 mg/day or 175.2 g/yr.
Shielding factor, inhalation	0.5	Shielding factor recommended by NUREG/CR-5512 and PG-8-08.
Shielding Factor, gamma	0.7	RESRAD default

[a] Parameter values listed for both industrial/construction and remedial worker scenarios unless otherwise stated.

place over an 80-hour period. The dose from this exposure takes the place of any normal outdoor exposure. This scenario is considered to account for unlikely events such as the construction of a deep elevator shaft for a new building. Because waste material would only be left in place under a partial excavation scenario with institutional controls, an exposure would occur only if controls fail.

Remediation Worker

The remediation worker is generally the same as the deep excavation worker in that he is only exposed outdoors during construction activities. Because this worker is only on site during remedial activities (ie, removal of radiologically contaminated soil), his occupancy varies by remedial alternative. For example, the partial removal of contaminated soil will take less time than complete removal.

C.2.1.3 Dose and Risk Characterization

RESRAD version 5.621 was used to estimate the dose and risk to each receptor. To estimate a dose or risk, the appropriate exposure parameters, the source term (concentrations of radionuclides), and other variables such as depth of contamination and distribution coefficients are selected to provide conservative yet realistic estimates of exposure. The exposure parameters describing the potential receptors are given above. The source term depends on the remedial alternative and is discussed below. The other variables are either left at the default values or site specific data are used.

C.2.1.4 Source Terms

The source term (or concentrations of radionuclides remaining in soil) depends on the remedial alternative. Six alternatives were evaluated as part of the SLDS FS assessment. They are:

4) No Action,
5) Institutional Controls (with no removal),
6) Consolidate and Cap,
7) Partial Excavation,
8) Complete Removal to the current most restrictive composite criteria, and
9) Selective Excavation.

This ALARA analysis is designed to define the amount of material which may be left in place after a partial excavation (Alternative 4) and still meet current guidelines for dose and risk. Ultimately the goal of this analysis is to provide data to support a remedy which will meet CERCLA risk requirements and satisfy MDNR concerns for potential radiation risk. That is, the source term for Alternatives 1 and 2 is already defined by current (baseline) conditions. The Alternatives 3 and 5 source term is defined by the composite criteria. The ALARA analysis defines how much material may be left in place after partial excavation while still limiting doses and risks with institutional controls in place, and with loss of those controls. For the purposes of dose and risk evaluation, Alternative 4 is considered an upper bound case for potential exposures under Alternative 6. To define the Alternative 4 source term, the following steps were followed:

- The site was broken into six exposure units (Units 1, 2, 6a, 6b, 6c, and 7 - named after the Mallinckrodt plant number in which they are located). This step is necessary because the contamination is non-contiguous, contains wide ranges of concentrations for different radionuclides, and is present at various stages of equilibrium.

- Six different cleanup criteria were considered representing a wide range of concentrations ranging from no action to cleaning to the current most restrictive composite criteria.

- RESRAD was used to estimate the dose from each of these exposure units at each concentration interval.

- The cost of each cleanup level was compared to the respective dose to identify the most reasonably achievable option.

Figure C-1 shows the location of each exposure unit. Table C-2 breaks out the range of cleanup options considered in the ALARA analysis. Note that the Option A (No Action) source is the same as the Alternative 1 and 2 source term, and the Option F source is the same as the Alternatives 3 and 5 source term. Under any cleanup option, the majority of the dose comes from the top few feet of soil whether it be from gamma radiation, soil ingestion, or dust inhalation. The results from the site-specific evaluation of the composite criteria (5 pCi/g in the top 6 inches and 15 pCi/g in the interval from 6–24 inches for radium and thorium, and 50 pCi/g for U-238) show that these criteria are protective under current and anticipated future land use. For this reason, each remedial action option utilizes the composite criteria for the top 2 feet. This approach is consistent with applicable PRGs as defined in Section 2.6.

Table C-2. Incremental Cleanup Options for Alternative 4 ALARA Analysis

Option	Exposure Units	Target Removal Levels for Ra-226/Th-230/U-238 (pCi/g)	
		Top 2 ft	> 2 ft
A [a]	1, 2, 6a, 6b, 6c, and 7	No Action	No Action
B	1, 2, 6a, 6b, 6c, and 7	composite criteria [b]	200/400/600
C	1, 2, 6a, 6b, 6c, and 7	composite criteria	100/200/300
D	1, 2, 6a, 6b, 6c, and 7	composite criteria	50/100/150
E	1, 2, 6a, 6b, 6c, and 7	composite criteria	15/40/100
F [c]	1, 2, 6a, 6b, 6c, and 7	composite criteria	composite criteria

[a] Also used to define Alternative 1 and 2 source terms. Option A is used as a boundary condition.

[b] 5 pCi/g for Ra-226, Th-230, Ra-228, and Th-232 in the top 6 inches, 15 pCi/g for Ra-226, Th-230, Ra-228, and Th-232 below 6 inches, and 50 pCi/g for U-238 at any depth. Based on combining 40 CFR 192 and DOE 5400.5 into composite criteria, including site specific dose assessment for uranium.

[c] Also used to define Alternative 4 and 5 source terms. Option F is used as a boundary condition.

The six exposure units were selected based on the following criteria:

- The areas must show relatively high levels of contamination,
- Areas should be large enough to reasonably model industrial exposure scenarios,
- The bulk of the contamination in the areas should fall below two ft in depth, it is assumed that the top two feet of contaminated soil will be removed to the composite criteria except for Option A, and
- If possible, the areas should represent different MED/AEC operations.

Residual concentrations for each option and exposure unit are listed in Table C-3 (top 8 ft). Table C-4 lists concentrations below 8 ft. To calculate residual concentrations, data in the site database were manipulated in the following manner:

- Data from a specified area were identified and stored in a separate data set,
- Results above the target removal level were removed from the data set,

Table C-3. Radionuclide Concentrations in Top 8 ft of Soil for Selected Exposure Units

No Action						
	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
Ra-226	61	69.2	14.6	38.9	5.02	358
Th-230	230	1180	212	62.3	41.6	211
Th-232	4.04	3.42	4.13	7.16	4.11	6.47
U-238	89.3	4180	682	130	34.5	145
Remove SOR > 1 (composite criteria) to 2 ft, and Ra/Th/U = 200/400/600 pCi/g						
	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	Plant 7
Ra-226	46	3.36	6.82	26	5.0	120
Th-230	230	8.85	28.7	23.4	3.65	32
Th-232	4.38	3.98	3.03	4.04	5.3	6.64
U-238	28.6	323	100	37.3	9.0	29.8
Remove SOR > 1 (composite criteria) to 2 ft, and Ra/Th/U = 100/200/300 pCi/g						
	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
Ra-226	5.0	3.68	6.61	17.8	5.0	26
Th-230	18	3.91	48.7	9.35	3.65	11
Th-232	1.0	4.51	3.03	3.78	5.3	9.66
U-238	36.9	133	47.1	34.1	9.0	30.4
Remove SOR > 1 (composite criteria) to 2 ft, and Ra/Th/U = 50/100/150 pCi/g						
	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
Ra-226	5.0	2.98	4.44	7.22	5.0	26
Th-230	18	2.18	6.32	6.33	3.65	11
Th-232	1.0	3.0	2.72	4.41	5.3	9.66
U-238	36.9	56	41.1	30.2	9.0	30.4
Remove SOR > 1 (composite criteria) to 2 ft, and Ra/Th/U = 15/40/100 pCi/g						
	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
Ra-226	5.0	2.98	5.3	6.5	5.0	4.0
Th-230	18	2.18	7.07	4.98	3.65	3.8
Th-232	1.0	3.0	3.57	6.2	5.3	4.0
U-238	36.9	56	33.7	22.3	9.0	31.7
Remove SOR > 1 (composite criteria)						
	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
Ra-226	2.0	4.0	4.91	6.23	2.3	4.0
Th-230	2.5	1.6	9.2	6.7	4.2	3.8
Th-232	1.0	2.56	2.51	4.41	1.6	4.0
U-238	1.1	23.7	22.2	16.2	9.0	31.7

Table C-4. Radionuclide Concentrations Below 8 ft of Soil for Selected Exposure Units

No Action

	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
Ra-226	3.0	3.2	3.25	26	1.3	5.0
Th-230	8.4	21	37	504	1.0	3.6
Th-232	3.0	2.9	2.7	3.1	2.0	5.0
U-238	310	28,000	1140	611	6.7	20

Remove Ra/Th/U = 200/400/600 pCi/g

	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
Ra-226	3.0	2.2	2.6	7.1	1.3	5.0
Th-230	8.4	1.7	7.7	53	1.0	3.6
Th-232	3.0	2.0	2.8	2.9	2.0	5.0
U-238	310	260	96	48	6.7	20

Remove Ra/Th/U = 100/200/300 pCi/g

	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
Ra-226	2.0	2.3	2.5	6.3	1.3	5.0
Th-230	3.2	1.7	8.1	15	1.0	3.6
Th-232	3.0	2.0	2.8	2.9	2.0	5.0
U-238	73	200	75	43	6.7	20

Remove Ra/Th/U = 50/100/150 pCi/g

	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
Ra-226	2.0	2.1	2.4	5.7	1.3	5.0
Th-230	3.2	1.6	5.6	8.0	1.0	3.6
Th-232	3.0	2.1	2.9	2.9	2.0	5.0
U-238	73	79	37	46	6.7	20

Remove Ra/Th/U = 15/40/100 pCi/g

	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
Ra-226	2.0	2.2	2.5	3.7	1.3	5.0
Th-230	3.2	1.5	9.6	7.4	1.0	3.6
Th-232	3.0	2.1	2.9	1.8	2.0	5.0
U-238	73	46	24	15	6.7	20

Remove SOR > 1

	UCL$_{95}$ Concentration After Removal (pCi/g)					
Radionuclide	**Plant 1**	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
Ra-226	0.9	2.3	2.4	3.8	1.3	5.0
Th-230	1.0	1.5	5.4	3.2	1.0	3.6
Th-232	1.1	2.1	2.6	1.8	2.0	5.0
U-238	1.3	16	13	15	6.7	20

- The upper 95 percent confidence level on the mean (UCL_{95}) was calculated for each radionuclide from the remaining results,

- Background was subtracted from each UCL_{95} to provide an estimate of the (residual) reasonable maximum exposure (RME) concentrations, and

- The residual RME concentrations were then used as the source term in dose and risk calculations.

For each source term calculation a 'sum of the ratios' (SOR) approach was used to determine the volume of contaminated soil associated with each remedial option. The SOR refers to the sum of the ratios of each radionuclide's concentration to the cleanup target. This SOR approach is a standard method to determine compliance with a concentration limit when multiple radionuclides are present. When the SOR is less than or equal to 1.0, the cleanup target is achieved.

DOE Order 5400.5 includes a limit for Th-230 and 40 CFR 192 does not. To be conservative and to be consistent with prior analyses at the St. Louis site, the DOE Order 5400.5 and 40 CFR 192 were combined (composite criteria) so that Th-230 was included in the SOR equations shown below.

For the top six inches of soil,

$$\text{SOR} = \frac{\text{MAX of (Th-230 or Ra-226)}}{5} + \frac{\text{MAX of (Th-232 or Ra-228)}}{5} + \frac{\text{(U-238)}}{50}$$

where all concentrations are net (above background) and the larger of Th-230 or Ra-226 and Th-232 or Ra-228 are selected. For soil below six inches, the equation changes to

$$\text{SOR} = \frac{\text{MAX of (Th-230 or Ra-226)}}{15} + \frac{\text{MAX of (Th-232 or Ra-228)}}{15} + \frac{\text{(U-238)}}{50}$$

Again, concentrations are net and the larger of Th-230 or Ra-226 and Th-232 or Ra-228 are selected. All concentrations are given in pCi/g. The equations shown above represent the baseline SOR formulas for compliance with composite criteria.

For the variations of target removal levels other than the composite, the SOR formula treats each principal radionuclide separately (since separate target removal levels are considered for each principal radionuclide). For example, if the proposed radionuclide limits are 15 pCi/g Ra-226, 40 pCi/g Th-230, and 100 pCi/g U-238 as under Option E, the SOR formula changes to the following:

$$\text{SOR(E)} = \frac{\text{(Ra-226)}}{15} + \frac{\text{(Th-230)}}{40} + \frac{\text{(U-238)}}{100}$$

For each of the other options listed in Table C-2 the formula is modified by replacing the denominators of the fractions with the target removal levels for that option.

When more than one isotope of concern is present, the use of the SOR principle ensures that the residual concentration will be much less than the target removal level for each individual radionuclide. For the SOR(E) example shown above, if Th-230 = 10 pCi/g and U-238 = 25 pCi/g, then Ra-226 must be less than 7.5 pCi/g or the soil would be removed.

Tables C-3 and C-4 show that by removing soil above a specified SOR criterion, residual soil concentrations are reduced to below that target removal level. By considering the "No Action" and "Remove ... 50/100/150 pCi/g" scenarios in Table C-3, it is clear that removing radionuclides above the 50/100/150 pCi/g target level reduces estimated residual concentrations to well below concentrations of 50 pCi/g for Ra-226, 100 pCi/g for Th-230, and 150 pCi/g for U-238. This relationship applies for all target removal levels.

C.2.1.6 Dose and Risk Estimates

Site Industrial/Construction Worker

The industrial scenario doses resulting from exposure to radionuclides at each SLDS exposure unit are listed in Table C-5. These dose estimates are calculated for the worker who performs construction/digging activities for 400 hours per year in addition to 1,725 hours per year of indoor light industrial work. Assuming there is no cover present, doses range from as high as 1,500 mrem/yr (no removal at Plant 2) to 4.3 mrem/yr (remove to SOR 1.0 at Plant 1).

A clear break in the no cover doses occurs after the removal of Ra/Th/U > 200/400/600 pCi/g (Option B) and again after the removal of Ra/Th/U > 100/200/300 pCi/g (Option C). It is evident from the no cover results that there are areas of localized contamination that contribute significantly to dose regardless of the option selected, especially near Plant 7 where Ra-226 is the primary contaminant. At other exposure units, doses are estimated to be less than 100 mrem/yr after Ra/Th/U above 100/200/300 pCi/g is removed (Option C). It is assumed that results listed in Table 2.5 under a no cover scenario represent the doses that would result after a loss of institutional controls. Based on the new NRC decommissioning rule (10 CFR 20 Subpart E), 100 mrem/yr is a limit for restricted release when controls (such as land use restrictions and cover) fail.

Table C-5 also lists doses assuming a 6-inch or a 2-ft cover is present. Under the partial removal alternative (Alternative 4) it is assumed that contamination in the top two feet will be removed to composite criteria limits. As noted in Table C-5, doses to future industrial workers will be less than 1 mrem/yr if two feet of cover is used to restore original grade. Assuming a minimum cover depth of 6 inches is maintained, doses are 12 mrem/yr or less to the industrial/construction worker if Ra/Th/U above 100/200/300 pCi/g are removed.

The industrial exposure scenario cancer risks resulting from exposure to radionuclides at SLDS exposure unit are listed in Table C-6. Assuming there is no cover present, cancer risks range from as high as 1.5×10^{-2} (no removal at Plant 2) to 3.5×10^{-5} (remove to SOR 1.0 at Plant 1). As with the dose results, a clear break in the no cover risks occurs after the removal of Ra/Th/U > 200/400/600 pCi/g (Option B) and again after the removal of Ra/Th/U > 100/200/300 pCi/g (Option C). As was evident in the dose results, localized areas contribute to elevated risk due to

Table C-5. Industrial/Construction Worker Dose Assessment Results in the Top 8 ft of Soil by Cover Depth

Removal Option	Dose by Exposure Unit - No Cover (mrem/yr)					
	Plant 1	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
A: No Removal	332	1514	276	167	55	1140
B: 200/400/600	293	56	52	93	29	387
C: 100/200/300	27	36	62	66	29	110
D: 50/100/150	27	20	22	35	29	110
E: 15/40/100	27	20	27	38	29	24
F: Composite Criteria (SOR > 1)	4.3	18	23	31	8.9	24

Removal Option	Dose by Exposure Unit - 6-Inch Cover (mrem/yr)					
	Plant 1	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
A: No Removal	36	146	27	17	6.4	112
B: 200/400/600	33	3.6	5.2	9.2	3.3	39
C: 100/200/300	2.6	2.9	7.0	6.5	3.3	12
D: 50/100/150	2.6	1.7	2.1	3.6	3.3	12
E: 15/40/100	2.6	1.7	2.7	4.2	3.3	2.4
F: Composite Criteria (SOR > 1)	0.3	1.7	2.3	3.3	0.9	2.4

Removal Option	Dose by Exposure Unit - 2-Ft Cover (mrem/yr)					
	Plant 1	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
A: No Removal	0.1	0.5	0.1	0.1	< 0.1	0.4
B: 200/400/600	0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1
C: 100/200/300	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
D: 50/100/150	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
E: 15/40/100	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
F: Composite Criteria (SOR > 1)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1

Table C-6. Industrial/Construction Cancer Risk Assessment Results in the Top 8 ft of Soil by Cover Depth

Removal Option	Risk by Exposure Unit - No Cover					
	Plant 1	Plant 2	Plant 6a	Plant 6b	Plant 6c	Plant 7
A: No Removal	3.6×10^{-3}	1.5×10^{-2}	2.8×10^{-3}	1.7×10^{-3}	6.2×10^{-4}	1.1×10^{-2}
B: 200/400/600	3.3×10^{-3}	4.2×10^{-4}	5.2×10^{-4}	9.0×10^{-4}	3.0×10^{-4}	3.8×10^{-3}
C: 100/200/300	2.7×10^{-4}	3.0×10^{-4}	6.9×10^{-4}	6.4×10^{-4}	3.0×10^{-4}	1.1×10^{-3}
D: 50/100/150	2.7×10^{-4}	1.8×10^{-4}	2.1×10^{-4}	3.5×10^{-4}	3.0×10^{-4}	1.1×10^{-3}
E: 15/40/100	2.7×10^{-4}	1.8×10^{-4}	2.6×10^{-4}	3.9×10^{-4}	3.0×10^{-4}	2.3×10^{-4}
F: Composite Criteria (SOR > 1)	3.5×10^{-5}	1.7×10^{-4}	2.3×10^{-4}	3.1×10^{-4}	8.6×10^{-5}	2.3×10^{-4}

Removal Option	Risk Exposure Unit - 6-Inch Cover					
	Plant 1	Plant 2	Plant 6a	Plant 6b	Plant 6c	Plant 7
A: No Removal	5.4×10^{-4}	2.2×10^{-3}	4.0×10^{-4}	2.5×10^{-4}	9.5×10^{-5}	1.7×10^{-3}
B: 200/400/600	5.0×10^{-4}	5.1×10^{-5}	7.6×10^{-5}	1.4×10^{-4}	4.8×10^{-5}	5.8×10^{-4}
C: 100/200/300	3.8×10^{-5}	4.1×10^{-5}	1.0×10^{-4}	9.7×10^{-5}	4.8×10^{-5}	1.7×10^{-4}
D: 50/100/150	3.8×10^{-5}	2.5×10^{-5}	3.1×10^{-5}	5.3×10^{-5}	4.8×10^{-5}	1.7×10^{-4}
E: 15/40/100	3.8×10^{-5}	2.5×10^{-5}	4.0×10^{-5}	6.2×10^{-5}	4.8×10^{-5}	3.6×10^{-5}
F: Composite Criteria (SOR > 1)	5.1×10^{-6}	2.6×10^{-5}	3.4×10^{-5}	4.8×10^{-5}	1.3×10^{-5}	3.6×10^{-5}

Removal Option	Risk by Exposure Unit - 2-Ft Cover					
	Plant 1	Plant 2	Plant 6a	Plant 6b	Plant 6c	Plant 7
A: No Removal	1.8×10^{-6}	6.8×10^{-6}	1.3×10^{-6}	8.5×10^{-7}	3.3×10^{-7}	5.3×10^{-6}
B: 200/400/600	1.6×10^{-6}	1.8×10^{-7}	2.6×10^{-7}	4.6×10^{-7}	2.0×10^{-7}	1.9×10^{-6}
C: 100/200/300	1.2×10^{-7}	1.6×10^{-7}	3.5×10^{-7}	3.3×10^{-7}	2.0×10^{-7}	6.4×10^{-7}
D: 50/100/150	1.2×10^{-7}	9.7×10^{-8}	1.1×10^{-7}	2.0×10^{-7}	2.0×10^{-7}	6.4×10^{-7}
E: 15/40/100	1.2×10^{-7}	9.7×10^{-8}	1.5×10^{-7}	2.5×10^{-7}	2.0×10^{-7}	1.4×10^{-7}
F: Composite Criteria (SOR > 1)	1.6×10^{-8}	9.6×10^{-8}	1.2×10^{-7}	1.9×10^{-7}	4.6×10^{-8}	1.4×10^{-7}

Ra-226 (eg, Plant 7). It is assumed that results listed in Table C-6 under a no cover scenario represent the risks that would result after a loss of institutional controls.

Table C-6 also lists cancer risks assuming a 6-inch or a 2-ft cover is present. Under the partial removal alternative (Alternative 4) it is assumed that contamination in the top two feet will be removed to composite criteria. As noted in Table C-6 if two feet of cover is used to restore original grade, risks to future industrial workers will be less than 1 × 10^{-5}. Assuming a minimum cover depth of 6 inches in maintained, risks generally fall within the 10^{-4} to 10^{-5} range.

Industrial/Utility Worker

Assuming that institutional controls are maintained at the site, workers performing deep excavations would be protected by personal protective equipment and safety plans to minimize exposure. Both the dose and risk limits would, therefore, be met if controls are maintained. However, under loss of these controls, dose limits would be exceeded in the Plant 2 exposure unit with the worst case worker dose estimated at approximately 200 mrem/yr under the no action alternative. As shown in Table C-7, doses to the industrial/utility worker are dramatically reduced with each partial removal option, with a significant drop to approximately 2 mrem/yr under Option C (remove Ra/Th/U > 100/200/300 pCi/g).

Table C-7. Industrial/Utility (Deep Excavation) Worker Doses for Removal of SLDS Contaminated Soil

Removal Option	Dose by Exposure Unit (mrem/yr) [a]					
	Plant 1	**Plant 2**	**Plant 6a**	**Plant 6b**	**Plant 6c**	**Plant 7**
A: No Removal	3.1	197	10	30	0.3	1.6
B: 200/400/600	3.1	156	1.5	3.8	0.3	1.6
C: 100/200/300	1.1	1.9	1.4	2.0	0.3	1.6
D: 50/100/150	1.1	1.0	1.0	1.6	0.3	1.6
E: 15/40/100	1.1	0.8	1.1	0.9	0.3	1.6
F: Composite Criteria (SOR > 1)	0.1	0.6	0.8	0.8	0.3	1.6

[a] Some results do not change down a column (with increasing remediation) partly because some areas do contain contaminated soil below 8 ft and/or because there may be limited data below 8 ft in that exposure unit.

Remediation Worker

Table C-8 lists the dose results for the remediation worker scenario. This scenario assumes that the entire SLDS property is remediated using the design target removal level (eg, for Option C, remove Ra/Th/U > 100/200/300 pCi/g). Because the more restrictive criteria result in more remediation and thus more exposure time, remediation worker doses increase with excavated volume. Assuming that remediation stops at eight ft, results indicate that worker doses range from a minimum of 279 mrem/yr (remove Ra/Th/U > 200/400/600 pCi/g) to a maximum of 635 mrem/yr (remove SOR > 1). If soils below eight feet are considered, the remediation worker doses increase to a minimum of 334 mrem/yr to a maximum of 976 mrem/yr. These remediation worker doses are occupational doses to a trained radiation worker (the federal dose limit for workers is 5,000 mrem/yr). In addition, these dose estimates do not include consideration of protective measures such as respiratory protection or shielding, and thus are very conservative estimates of likely doses.

Table C-8. Remediation Worker Doses for Removal of SLDS Contaminated Soil

Removal Option	Dose Rate (0-8 ft) (mrem/yr)	Dose Rate (> 8 ft) (mrem/yr)	Total Dose Rate (mrem/yr)
A: No Removal [a]	0.0	0.0	0.0
B: 200/400/600	279	55	334
C: 100/200/300	300	96	396
D: 50/100/150	365	161	526
E: 15/40/100	501	240	741
F: Composite Criteria (SOR > 1)	635	341	976

[a] If soils are left in place, the remediation worker has no exposure

Indoor Radon

Site workers are also potentially exposed to indoor radon (Rn-222) originating from residual Ra-226 concentrations in soil. 40 CFR 192 limits indoor radon to 0.03 working levels (WL), including background, in any occupied or habitable building, with an objective for remedial action of 0.02 WL. For this assessment, RESRAD was used to model potential indoor radon concentrations under industrial exposure conditions. Using an average air exchange rate of 1 air exchange per hour to simulate industrial structures, an average working level per unit pCi/g of Ra-226 was determined. This analysis showed that under industrial conditions, Ra-226 soil concentrations must be 18 pCi/g for Rn-222 to reach 0.02 WL. For future conditions (to 1,000 years) the Th-230 contribution to radon (through ingrowth and decay of Ra-226) must also be considered. Based on this analysis, a concentration of approximately 54 pCi/g of Th-230 in soil is needed to provide sufficient Ra-226 to cause indoor radon of 0.02 WL at 1,000 years.

C.3 NON-RADIOLOGICAL RISK

Non-radiological risk is broken into two main categories: risk from construction activities and risk from transportation of waste and borrow soil. Because risk from construction and transportation are often orders of magnitude higher than the risk from exposure to residual radioactivity (as at SLDS), radiation and non-radiation risks are not summed. Radiological and non-radiological risks are also not summed because they measure different types of risks (death from cancer versus fatal injury) that are not compatible. These non-radiation risks are provided for comparison purposes and for consideration in the overall analysis of ALARA for SLDS (ie, ALARA curves for cost versus construction or transportation risk are not provided).

C.3.1 CONSTRUCTION RISK

Construction-related fatalities for Alternative 4 (partial excavation) were estimated assuming a fatality rate of 4.2×10^{-8} fatalities per person-hour (NUREG/CR-1266). Table C-9 lists construction risk estimates by option and depth interval. Depth interval is considered because the duration of excavation activities can increase dramatically when excavation activities proceed beyond eight feet. Note also that one risk factor is used for all activities independent of excavation depth. Results indicate that for the worst case scenario (excavation to the lowest cleanup criteria) there is approximately a 3 in 1,000 chance of fatal accident while performing construction activities in the top 8 feet of soil. If excavation proceeds to below 8 feet, there is an additional 1 in 1,000 chance of fatality.

Table C-9. Non-Radiological Risk Estimates for SLDS Remedial Activities

Removal Option	Risk of Fatality (Construction)		
	Top 8-ft	Below 8-ft	Total
A: No Action	0.0	0.0	0.0
B: 200/400/600	1.2×10^{-3}	5.6×10^{-5}	1.3×10^{-3}
C: 100/200/300	1.3×10^{-3}	1.8×10^{-4}	1.5×10^{-3}
D: 50/100/150	1.7×10^{-3}	2.9×10^{-4}	2.0×10^{-3}
E: 15/40/100	2.3×10^{-3}	5.5×10^{-4}	2.9×10^{-3}
F: Composite Criteria (SOR > 1)	3.0×10^{-3}	1.0×10^{-3}	4.1×10^{-3}
Removal Option	**Risk of Fatality (Transportation)**		
	2 - 8 ft	**Below 8-ft**	**Total [a]**
A: No Action	0.0	0.0	0.0
B: 200/400/600	8.1×10^{-4}	1.6×10^{-3}	8.1×10^{-3}
C: 100/200/300	2.0×10^{-3}	3.5×10^{-3}	1.1×10^{-2}
D: 50/100/150	4.9×10^{-3}	7.7×10^{-3}	1.9×10^{-2}
E: 15/40/100	1.6×10^{-2}	1.4×10^{-2}	3.6×10^{-2}
F: Composite Criteria (SOR > 1)	3.4×10^{-2}	2.9×10^{-2}	6.9×10^{-2}

[a] Includes 5.7×10^{-3} risk for shipping contaminated soils in the top 2 ft.

C.3.2 TRANSPORTATION RISK

Fatalities caused by transportation of excavated soil and borrow for backfill are assumed to occur at a rate of 3.8×10^{-8} fatalities per mile (NUREG/CR-1266) for transport by truck or 4.52×10^{-8} fatalities per mile (Cashwell et al. 1989) for transport by train. It is assumed that all excavated soil is loaded onto gondolas on site and that all shipments are made by train to a commercial disposal facility. Ten gondolas per train is assumed. Transport of borrow is assumed to be performed using trucks that haul 10 yd^3 per trip from a facility 50 miles from SLDS. Table C-9 shows that there is approximately an 8 in 1,000 to 7 in 100 chance of fatality related to the shipment of soils if a remedial action is implemented.

C.4. COST ANALYSIS

The cost for each remedial option considered in Section 2 above includes individual costs of excavation and backfill, loading and transportation of waste, disposal of waste, site controls (such as monitoring and surveillance, as appropriate), and program support and contingencies. As a starting point, the volume of material excavated is estimated using the site database and earthVision® software. The earthVision® software provides 3-D models of site data and estimates of in situ volume. The volume for each remedial alternative is the cornerstone of the respective cost estimate. That is, duration of excavation, volume of required backfill, transportation costs, disposal costs, monitoring methods, program support requirements, and other variables not listed here all depend on the in situ volume estimate.

The cost (and volume) estimate provides two major variables for this dose assessment and ALARA analysis: (1) the cost of remedial Options A-F for comparison to residual dose trade-off, and (2) the duration of excavation activities for estimating the dose to remediation workers. Other variables support the ALARA analysis but are less significant and are not listed for brevity.

C.4.1 ALARA COST ESTIMATE

The purpose of the ALARA cost estimate was to provide a relative comparison of cost for the range of partial excavation options. Conditions for each partial excavation option were made as similar as possible so that a valid comparison of the impact of different target removal levels could be assessed. Costs were also estimated for each remedial option (A-F) using two depth intervals (0-8 ft and below 8 ft) to provide an understanding of the relative impact of excavation below the saturated zone at SLDS. For consistency across options, and to support assessment of short-term construction and transportation risks, only accessible soils were considered in the ALARA cost estimate. Thus costs in the ALARA cost estimate will differ from the final costs shown for alternatives in the Feasibility Study. As previously noted, the ALARA cost estimates are only used for assessment of optimum target removal levels for Alternative 4. For Alternative 4 (partial removal), contaminated soil in the top two feet will be excavated to the composite criteria under all removal options except A. Therefore, the estimated volume of soil for each remedial option includes 34,076 yd^3 of surface soil. As shown in Table C-10, significant increases in volume occur between Options D and E and again between Option E and F. Significant cost differences occur at the same intervals.

C.5 ALARA ANALYSIS

The goal of this ALARA analysis is to estimate appropriate radionuclide cleanup concentrations for Alternative 4 (partial excavation) while considering the cost of remediation, the radiation dose to likely future site employees, and the radiation dose and non-radiation risk to remediation workers. As part of this analysis, dose estimates were calculated for future employees and remediation workers while considering six remedial options (ie, six different target radionuclide removal levels). Construction and transportation related risk was also estimated considering the same six remedial options. Finally, the excavation volume and cost of each remedial option were estimated. All of these factors were included in the analysis of ALARA for the SLDS site.

Table C-10. Remedial Option Costs[a] and Volumes by Depth Interval

Removal Option	0 to 8-ft		Below 8-ft		Total All Depths	
	Cost ($M)	Volume (yd^3)[b,c]	Cost ($M)	Volume (yd^3)[b,c]	Cost ($M)	Volume (yd^3)[b,c]
A: No Action	—	0	—	0	22	0
B: 200/400/600	58	34,773	10	1,430	68	36,203
C: 100/200/300	59	35,768	12	3,008	71	38,776
D: 50/100/150	63	38,248	15	6,653	78	44,901
E: 15/40/100	69	48,118	19	12,282	88	60,400
F: SOR > 1	83	63,105	31	24,796	114	87,901

[a] Costs based on excavation and backfill, transportation, and disposal actions for accessible soils.

[b] All options include 34,076 yd^3 from the removal of top 2 ft of contaminated soil. Soil volumes under currently operational facilities and railroads are not considered.

[c] Volumes are accessible in situ estimates not including overburden. Estimates contain some round-off error that may result in slight (1–2 yd^3) differences between values shown here and in Appendix B of the FS. These rounding differences do not influence the final results of the analysis.

Before addressing the SLDS site as a whole, two exposure units are considered separately. Exposure unit 7 (Plant 7) contains relatively high Ra-226 concentrations in surface soils that result in higher doses using the current exposure model. This exposure unit is relatively small with localized shallow contamination. Because the Ra-226 concentrations produce doses four to six times higher than the other exposure units under most cleanup scenarios, and because the potential volume and cost impact is minimal, exposure unit 7 should be considered for remediation to the composite cleanup criteria. Exposure unit 2 (Plant 2) contains some relatively high radionuclide concentrations in soil below 8 ft in depth. These concentrations result in approximately a 200 mrem dose estimate for the deep excavation worker. Exposure at all other units are below regulatory limits. Given that the contamination in the top 8 ft of Plant 2 represents a large volume of material covering a large surface area, it is reasonable to assume that Plant 2 soils could be excavated to below 8 ft in order to provide additional assurance that an unlikely deep excavation does not result in significant dose under a loss of control scenario. (Doses and risks associated with loss of institutional controls are represented by the 'no cover' sections of Tables C-5 and C-6.)

If the Plant 2 area is remediated to depth (not limited to top 8 feet), it is prudent under an ALARA process to consider the additional volume of soil that would need to be excavated under each option to achieve complete excavation to depth for each cleanup criterion. The additional accessible in situ soil volume that would have to be excavated under this concept ranges from 285 yd^3 to 12,387 yd^3 under the cleanup criteria considered (options B–F). For the mid-point case (option D, 50/100/150 guidelines), this additional volume is 2,375 yd^3. Because this volume is minimal in comparison to the total site volume, remediation to complete depth of contamination should be considered for Alternative 4.

Figure C-2 plots cost vs. average dose under industrial/construction worker exposures for each partial removal remediation option. The summary doses shown in Figure C-2 represent the most likely potential industrial/construction worker exposure scenario (ie, exposures to the top 8 ft.

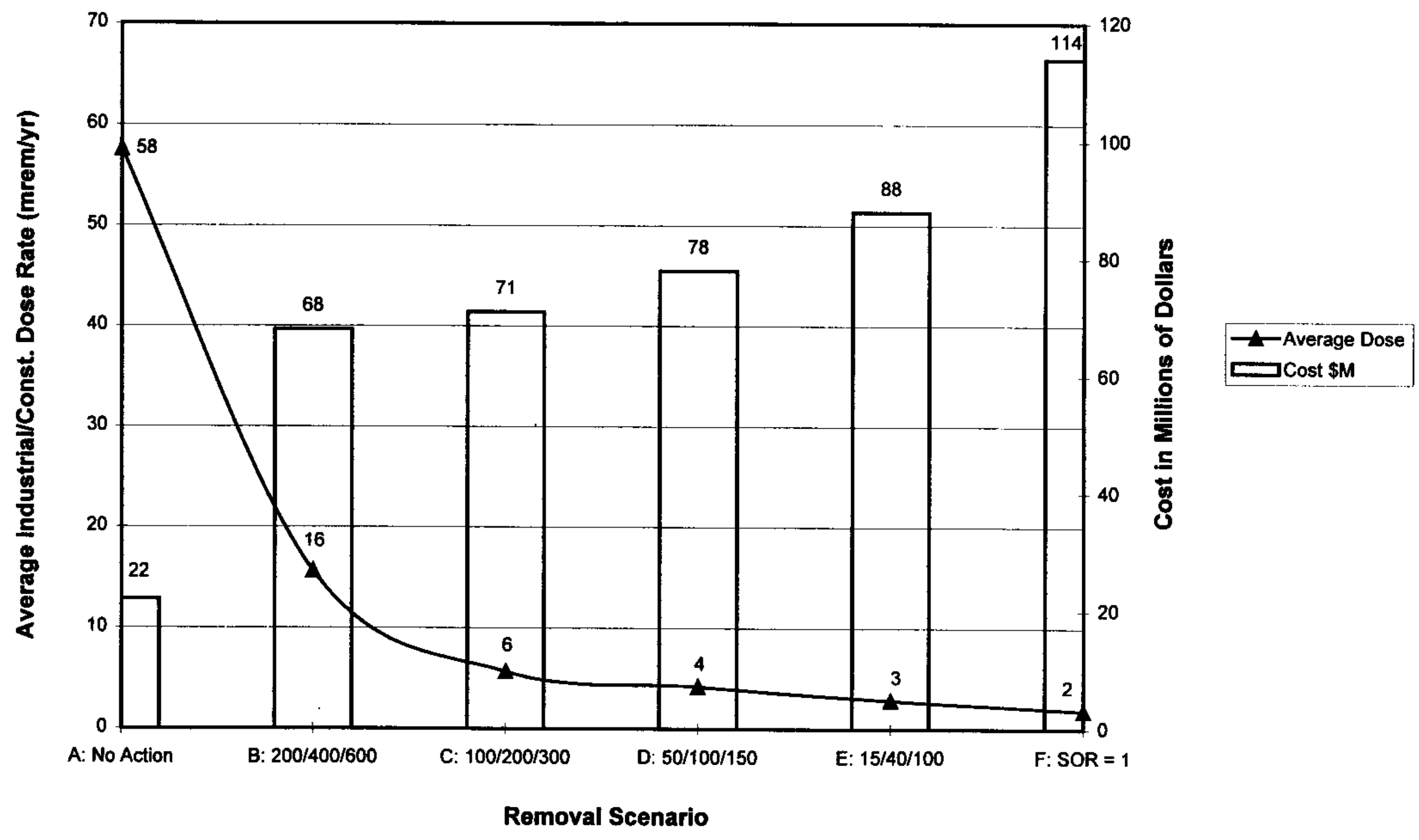

Figure C-2. Industrial Scenario ALARA Curves (6-inch Cover Assumed) of soil). These doses are based on RME conditions averaged across the 6 plant exposure areas. This plot shows that costs remain relatively steady for Options B through D primarily because volumes do not vary significantly. Option E shows a 10 million dollar increase over Option D (an additional 15,500 yd^3) and Option F shows an additional 36 million dollar increase (43,000 yd^3 over Option D). All removal options show an estimated industrial worker doses below 25 mrem/yr and risks in the 10^{-5} range. The doses for Options C through F range from 6 to 2 mrem/yr, practically indistinguishable values considering the uncertainties and conservative nature of the model. Based on the results plotted in Figure C-2, Options C through E could be considered reasonable cleanup goals noting that Option E includes an additional 10 million dollar cost and negligible drop in dose. Table C-11 lists the results of the ALARA analysis for Options C, D and E including collective dose estimates and non-radiological risks.

Table C-11. ALARA Analysis Results for Preferred Alternatives

ALARA Variable	Option C: (100/200/300)	Option D: (50/100/150)	Option E: (15/40/100)
Cost ($Million) (accessible soils only)	71	78	88
Volume (yd^3) (accessible soils only)	38,376	44,901	60,400
Industrial Risk with Controls [a] (lifetime^{-1})	1.0×10^{-4}	5.3×10^{-5}	6.2×10^{-5}
Industrial Dose with Controls [a] (mrem/yr)	7.0	3.6	4.2
Industrial Dose Controls Lost (mrem/yr)	66	35	38
Collective Industrial Dose (person-rem/yr)	1.4[b]	0.72[b]	0.84[b]
Remediation Dose (mrem/yr)	396	526	741
Collective Remedial Dose (person-rem/yr)	0.86	1.8	4.9
Transportation Risk	7.7×10^{-3}	1.1×10^{-2}	2.2×10^{-2}
Construction Risk	1.5×10^{-3}	2.0×10^{-3}	2.9×10^{-3}

[a] To be conservative, controls are assumed to be 6-inches of clean cover. Actual controls will include up to 2-ft of clean cover (reducing doses to < 1 mrem/yr). Doses and risks from the Plant 7 exposure unit are not considered in this table based on the assumption that this area will be cleaned to generic federal limits.

[b] Industrial dose × 200 (the estimated number of people working in impacted areas)

Remediation doses and non-radiological risks were calculated (and tabulated for Options C, D, and E in Table 5.1) for this ALARA analysis. This information is presented as part of the ALARA process to provide a measure of balance between the dose and risk that may result from a future site worker's exposure to residual radionuclides and the significantly higher doses and risk associated with completing a remedial action. In general, remediation worker doses range from 396 -741 mrem/yr for excavation to depth of contamination; estimated chance of a fatal construction accident is approximately 3 in 1,000; and the chance of a fatal train or traffic accident is 1 in 100 to 1 in 1,000 (depending on the selected option). Transportation risk did not drive selection of any alternative.

For the remediation of soils below eight feet, the additional cost is approximately the same for Options C, D, and E (averaging $15 million). The benefit of this additional excavation is that worker exposures under deep excavation scenarios would be well below the 100 mrem/yr limit after loss of institutional controls, and source material is removed from the saturated zone, minimizing potential future impact to groundwater.

C.6 UNCERTAINTIES

C.6.1 Parameter Assumptions

Exposure parameters were selected to provide a conservative, yet reasonable, estimate of potential radiological dose and risk to each receptor. Site-specific measurements and data were used, where available, to describe site conditions as accurately as possible. Where site-specific data were not available, standard default values recommended by NRC or other authorities or RESRAD default values were used. Exposure scenarios and parameter values have been consistently chosen to provide conservative, yet reasonable, estimates of potential radiation dose and risk, in accordance with the federal guidance to reduce potential radiation exposures to ALARA.

C.6.2 Identification of Areas of Elevated Radioactivity

Six separate areas were considered in this assessment. Those areas contain the highest relative radionuclide concentrations to produce a reasonable worst case exposure scenario. Likely exposure scenarios would include a receptor being exposed to several areas over a period of time and/or periods of occupancy in areas that contain no residual radioactivity. That is, the assumption that an industrial/construction worker would spend 25 years in one 2,500 m^2 area containing residual radioactivity exposed at the surface is highly improbable.

C.6.3 Target Removal Levels vs. Residual Concentrations

Target Removal levels have been identified for each remedial option (eg, Ra-226/Th-230/U-238 = 50/100/150 pCi/g). These action levels represent the concentrations that, if encountered, would be removed. As a result of this action, and the physical constraints associated with soil excavation (i.e. over excavation) the residual concentrations after removal would be much less than the target removal level. As can be seen in Tables C-3 and C-4, the residual concentrations are in all cases much less than the target removal level. These concentrations would be reduced further if approved borrow were incorporated.

C.6.4 Impact of Reuse of Overburden Material

As part of Alternative 4, overburden material containing less than the ALARA criteria concentrations may be used as backfill below 2 ft. It is likely that backfill material would consist of some combination of approved offsite borrow and overburden material less than the ALARA criteria. To assess the potential impacts and uncertainties associated with this component of Alternative 4, a screening analysis was conducted to provide an upper bound estimate of potential doses and risks associated with exposure to backfill material. This assessment assumed that the backfill material would consist of soil containing concentrations equal to a SOR of 1.0 based on the

ALARA criteria (50/100/150). The source term for this material was based on concentrations of the primary radionuclides that equate to a SOR of 1 for the ALARA criteria (ie, 16.7 pCi/g Ra-226, 33.3 pCi/g Th-230, and 50 pCi/g U-238). The appropriate decay products were included in this analysis (including Pa-231 and Ac-227) at concentrations based on the values listed above for the primary radionuclides.

Doses and risks were calculated for this screening analysis based on the industrial/construction worker scenario described previously in Section C.2.1.2. The results from this analysis show that if 6 in. of approved borrow or other clean material is applied (the expected condition), maximum industrial/construction worker doses and risks are projected as 8 mrem/yr and 1×10^{-4}, respectively. These values are within the ranges projected by the ALARA analysis for Option D (as shown in Tables C-5 and C-6), and thus the impact of reuse of overburden material on future doses and risks is expected to be minimal.

In addition, an analysis of the difference in sitewide average (UCL_{95} on the mean) concentrations was performed for the cases where overburden is left onsite or removed. On a sitewide basis [for the ALARA criteria (50/100/150)], the increase in the UCL_{95} concentrations between removing overburden and leaving overburden onsite was 2% for Ra-226, 2% for Th-230, 2% for Th-232, and 8% for U-238. These differences are negligible and support the concept that potential doses and risks will not be significantly impacted by use of below criteria overburden.

C.6.5 Volume Estimates

The volume of contaminated soil removed under each remedial option was estimated using data from the site database and earthVision® software. The volume estimates are ultimately limited by the density of data across the site and with depth. Given that the data at SLDS is limited in some areas and does not always bound contamination, the volume estimate is a source of uncertainty for the ALARA analysis.

Cost estimates are based in a large part on the projected volume and location of contaminated soils. Assuming that all parameters besides volume are accurate and without uncertainty, the volume estimate alone can still result in significant uncertainty in final cost estimates. In reality, all parameters chosen for the cost estimates are subject to uncertainty. Conservatism is practiced to account for this uncertainty to help assure that the uncertainty in the cost models will result in an overestimate of total cost. This unavoidable practice results in additional uncertainty in the ALARA analysis.

C.7 CONCLUSION

Results of the ALARA analysis indicate that Option D (remove Ra/Th/U of greater than 5/5/50 pCi/g in the top 6 in., remove greater than 15/15/50 pCi/g between 6 and 24 in., and remove greater than 50/100/150 pCi/g to depth) is the most appropriate selection for the SLDS. This alternative is protective of human health and the environment for current and anticipated future land uses and assures that residual risk is acceptable in the event of loss of institutional controls.

Selection of this alternative is based on residual risk and associated radiation dose, the total cost of remediation, and reduction of potential groundwater impact through removal of additional contaminated material from the saturated zone. This alternative complies with ARARs and site-specific criteria for surface and subsurface soils while minimizing cost through use of below criteria backfill.

Potential doses and risks associated with loss of institutional controls are shown under the 'no cover' sections of Tables C-5 and C-6. The anticipated future site conditions include cover material of at least 6 in. of approved borrow (to support vegetation) or asphalt for roadway and process areas. If institutional controls are maintained as anticipated, the best estimate of future doses and risks is provided under the '6-inch cover' entry in these tables. If institutional controls are lost and cover is no longer maintained, the best approximation of future doses and risks is shown under the 'no cover' sections of these tables. These results show that with the exception of the Plant 7 area, doses are less than the NRC criterion of 100 mrem/yr for loss of institutional controls using the 50/100/150 criteria.

Based on these results, and consistent with the ALARA philosophy, it is reasonable to apply the more stringent composite criteria at all depths in the Plant 7 area. By removal of the primarily Ra-226 contamination at this location to the more stringent criteria, worker doses are reduced (with and without institutional controls), and potential future radon mitigation is avoided with a small increase in volume removed. As shown in Table C-5, worker doses under a loss of institutional controls scenario (loss of cover) for the Plant 7 area would be reduced from 110 mrem/yr (50/100/150 criteria) to approximately 24 mrem/yr with the composite criteria.

In addition, results from this analysis show that it would be reasonable to apply the Alternative 4 cleanup guidelines to all depths of contamination at the site (ie, there is not a significant benefit to stopping excavation at 8 ft.). This approach provides benefits both from reduced potential deep excavation worker dose as well as increased source term removal for groundwater protection.

In summary, results from this ALARA analysis suggest the following major components for the remedy at SLDS:

- Excavation of accessible soils in the surface to 2-ft depth interval which exceed composite criteria of 5 pCi/g in the surface, and 15 pCi/g in the subsurface for the Ra-226, Ra-228, Th-230, and Th-232 and 50 pCi/g for U-238 at all depths.

- Excavation of accessible soils in the Plant 7 exposure unit to the composite criteria to depth of contamination.

- Excavation of accessible soils at all depths across the site using the risk-based target removal levels of 50 pCi/g for Ra-226, 100 pCi/g for Th-230, and 150 pCi/g for U-238. As part of this remediation localized areas of elevated contamination would be addressed using the methods outlined in the Multi-Agency Radiation Site Survey and Investigation Manual (MARSSIM).

- Use of institutional controls and site monitoring (including CERCLA 5-year reviews) to assure that industrial use is maintained at the site, and inaccessible soils do not present problems if future activities allow access to those soils.
- A final site survey will be conducted in accordance with MARSSIM.

C.8 REFERENCES

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ANNEX TO APPENDIX C

Appendix C showed that a partial removal Alternative (4D) using the composite criteria for shallow (< 2 ft) soils and ALARA criteria (target removal levels of 50 pCi/g Ra-226, 100 pCi/g Th-230, and 150 pCi/g U-238) for deeper soils is protective based on NRC and EPA guidelines. Removal of soils to deeper depths using the most restrictive criteria composite should thus provide additional protection.

An additional alternative (Alternative 6) has been added to the FS since the ALARA analysis was developed. This alternative moves excavation to the composite criteria across SLDS to depths of 4 or 6 feet, and use of the ALARA criteria for deep soils. Alternative 6 is defined as follows:

- Remediate 6 feet to composite criteria in Plants 1, 2, 3, 8, 9, and 10, under and around Buildings 116 and 117 in Plant 6, and Buildings 704-707 in Plant 7;
- Remediate 4 feet under streets, the remainder of Plants 6 and 7, Lot 7E, and vicinity properties;
- Remediate soils above the ALARA criteria below the 4–6 feet layer; and
- Backfill excavations using approved off-site borrow.

Doses and risks associated with industrial/construction worker exposures under Alternative 6 will be similar to doses and risks estimated for Alternative 4 since the same target removal levels are used for both alternatives. Since Alternative 6 involves excavation to the most stringent criteria to depths greater than used for Alternative 4, doses and risks associated with Alternative 6 will in many areas be much less than shown in the ALARA assessment for Alternative 4. Since Alternative 4 has been shown to be protective, and reduces doses and risks to ALARA, doses and risks were not recalculated for Alternative 6. Instead doses and risks associated with Alternative 4 are considered to be upper-bound values for Alternative 6.