**OFFICE OF FEDERAL AND STATE MATERIALS**
**AND ENVIRONMENTAL MANAGEMENT PROGRAMS**

# SAFETY EVALUATION REPORT RELATED TO APPROVAL OF MALLINCKRODT INC.'S PHASE 2 DECOMMISSIONING PLAN LICENSE NO. STB-401 DOCKET NO. 40-6563

**COVIDIEN MALLINCKRODT, INC.**
**ST. LOUIS, MISSOURI**

## 1. INTRODUCTION

On May 14, 2003, Covidien Mallinckrodt Inc. (Mallinckrodt or the licensee) submitted a license amendment request to authorize decommissioning as proposed in its Phase 2 Decommissioning Plan (DP) (ADAMS Nos.: ML032110490, ML032600825, ML032600898, ML032600901, ML032600945, ML032600956). In response to U.S. Nuclear Regulatory Commission (NRC) requests for additional information dated December 16, 2004 (ML043630359), June 29, 2005 (ML051430360), and February 16, 2006 (ML060310346), Mallinckrodt provided supplemental information on August 1, 2005 (ML052160048), September 1, 2005 (ML052520039), March 24, 2006 (ML060870482), April 21, 2006 (ML061240378), and July 20, 2006 (ML062060332). To make the Phase 2 DP a stand-alone document, Mallinckrodt submitted a completely revised Phase 2 DP, which incorporates the above revisions, on October 14, 2008 (ML083150652). Minor revisions to the DP were submitted on June 3, 2010 (ML101620140).

The ultimate goal of the columbium - tantalum (C-T) project decommissioning is to remediate those areas of the site associated with C-T production, to the extent necessary, to terminate License STB-401. Mallinckrodt elected to decommission the C-T project areas of the site in two phases. In Phase 1, Mallinckrodt decommissioned the buildings and equipment to the extent necessary to meet NRC's criteria for unrestricted release. Phase 1 of the decommissioning project was completed in February 2007. Phase 2 will include the remediation of the building slabs and foundations, paved surfaces, and all subsurface materials. This Safety Evaluation Report (SER) applies to the Phase 2 decommissioning activities. Much of the information contained in this SER was taken directly from the Mallinckrodt Phase 2 DP.

## 2. BACKGROUND

Mallinckrodt has been operating at the St. Louis Plant site since 1867, producing various products including metallic oxides and salts, ammonia, organic chemicals, and various uranium compounds for the Manhattan Engineering District and the Atomic Energy Commission (MED-AEC). The Mallinckrodt site, comprised of over 50 buildings on approximately 43 acres, is subdivided into smaller areas, called "Plants", based on the similarity of operations being performed. C-T processing and support occurred in 21 buildings. Although C-T production occurred within Plant 5, support activities were conducted in portions of Plants 1, 3, 6, 7 and 8.

In 1961, pursuant to 10 CFR Part 40, Mallinckrodt was issued a source material license (License No. STB-401) authorizing the possession and use of materials containing uranium

and thorium isotopes. From 1961 to 1985, Mallinckrodt extracted C-T from natural uranium ores and tin slags, and purchased and processed materials for C-T production. C-T processing was shut down from 1985 through early 1987, when Mallinckrodt began a two month pilot production run. During the pilot production run, approximately 20,000 pounds of tin slag were processed. Since 1987, no C-T processing has occurred at the site. In July 1993, NRC amended Mallinckrodt's license to a possession only license for decommissioning and license termination. Approximately 6 Curies (Ci) of natural uranium and 19 Ci of natural thorium isotopes were contained in the ores and tin slags processed under License STB-401.

## 3. SAFETY EVALUATION

### 3.1 Executive Summary

The DP contains an Executive Summary which includes all information identified in Section 16.1.2 of NUREG-1757, Vol. 1, Rev. 2. The information provided is general in nature. Detailed discussions of the facility description, extent of contamination, decommissioning activities, and clean-up criteria are provided in other sections of the DP. The staff notes that the Executive Summary states that Mallinckrodt's objective during Phase 2 is to decommission grade-level and below-grade building slabs, paved surfaces, and subsurface materials affected by former C-T operations, such that these areas meet NRC's criteria for unrestricted release and Mallinckrodt's license can be terminated by license amendment. The Executive Summary contains sufficient detail for the staff to conclude that the decommissioning activities and schedule appear to be reasonable.

### 3.2 Facility Operating History

Chapter 2 of the DP provides a detailed description of the facility operating history including MED-AEC activities, NRC licensed activities, previous decommissioning activities, descriptions of past spills and releases, and description of on-site burials.

NRC staff has reviewed the information in the "Facility Operating History" section of the DP for the Mallinckrodt facility, license number: STB-401, located at 3600 North Second Street, St. Louis, Missouri, 63147 according to the Consolidated Decommissioning Guidance, Vol. 1, Section 16.2 (Facility Operating History). Based on this review, NRC staff has determined that Mallinckrodt has provided sufficient information to aid NRC staff in evaluating the licensee's determination of the radiological status of the facility and the licensee's planned decommissioning activities, to ensure that the decommissioning can be conducted in accordance with NRC requirements. (Note — this finding incorporates the results of the staff's assessment under Sections 2.2, 2.3, 2.4, 2.5 and 2.6 below).

#### 3.2.1 MED-AEC Activities

Between 1942 and 1958, uranium processing and waste management activities were conducted by Mallinckrodt in support of early Federal Government programs to develop atomic weapons under the MED-AEC. These activities resulted in radiological contamination on Mallinckrodt property and properties adjacent to the site. The contamination at these locations consists of natural uranium and natural thorium and their associated progeny, including Th-230 and radium. Contamination is present in groundwater, soils, and structures. Contamination that is associated with MED-AEC activities is being separately remediated by the U.S. Army Corps of Engineers (USACE) under the Formerly Utilized Sites Remedial Action Program (FUSRAP).

In April 1942, Mallinckrodt, then called Mallinckrodt Chemical Works (MCW), was contracted to extract uranium from ore concentrates for eventual use in the first self-sustaining nuclear chain reaction in the graphite reactor being built at the University of Chicago. The initial contract was signed on July 20, 1942. Within 50 days of accepting the assignment from the War Department, MCW began producing highly refined uranium dioxide ($UO_2$) for the CP-1 pile reactor at the rate of 1 ton per day. Manufacturing was performed in Plant 2 (Buildings 50, 51, 51A, and 52), with research and other support activities in Plant 1 (Buildings A, K, X, and 25). The $UO_2$ was also shipped to another MED site for reduction to metallic fuel for the reactor. The intermediary products, uranyl nitrate and uranium trioxide, were produced both as intermediaries to the production of uranium dioxide and as final products. A process to convert $UO_2$ to uranium tetrafluoride, as a batch process, began in 1942. A process to convert uranium tetrafluoride to uranium metal started in 1943. This activity was performed in process buildings located on the east side of Broadway Street, immediately west of Plant 5. At that time, this area was designated as Plant 4. This area is currently designated as Plant 10. The company was the sole supplier of uranium compounds for the Manhattan project well into 1943, and provided high purity uranium products for the duration of the war.

In 1945, the Destrehan Plant (Plants 6 and 7) was built to process pitchblende ore and to increase the capacity of the refinery. Production began in 1946. In 1958, the Destrehan plant was put on standby, and uranium processing was transferred elsewhere.

In 1950 and 1951, the MED-AEC facilities in Plants 1 and 2 were partially decommissioned. In 1960 and 1961, the decommissioning of Plants 1 and 2 was completed, and Plant 4 and the Destrehan Plant were decommissioned. These decommissioning activities were performed to the standards of the day, and additional decontamination and remediation activities have been and are being performed under FUSRAP.

The St. Louis Plant processed approximately 50,000 tons of uranium products from ore concentrates and pitchblende ore during the 1942-1958 MED-AEC operations. It is estimated that the minimum radioactivity throughput was approximately 30,000 Ci of uranium isotopes and 10 Ci of thorium isotopes.

From 1956 to 1960, Mallinckrodt extracted columbium, tantalum, uranium, thorium, and rare earth elements from euxenite mineral ore for delivery to the AEC and the General Services Administration (GSA) as part of the Defense Materials Procurement Program. The Euxenite operation was performed under AEC source material license R-226. The license expired in 1960. It is estimated that a total of 95 Ci of natural uranium (U-238, U-234, and U-235) and 10 Ci of natural thorium (Th-232, Th-228) were contained in the ore processed during this time period. Building 238 was constructed to house Euxenite operations and subsequently adapted for use by C-T operations.

From 1956 to 1977, Mallinckrodt subdivided and/or resold small quantities of uranyl nitrate, uranyl acetate, and thorium nitrate salts under AEC/NRC licenses SUB-176 and later SUC-872. Maximum licensed quantities were 450 pounds (each) uranyl salts and 400 pounds thorium salts. Licensed activities were performed in Buildings 43, 62, and 80. Buildings 43 and 80 were previously demolished. A report of Mallinckrodt's final radioactivity survey under SUC-872 was submitted to NRC on December 13, 1979.

From 1956 to 1961, Mallinckrodt performed research and pilot studies under License SNM-276 to support the design of a reactor fuel rod production facility that was later constructed at Hematite, Missouri. Laboratory support was provided for a time following facility construction.

The pilot plant was located in the original Building 5. This building has been demolished. Laboratory analysis was performed in Building 25.

3.2.2 NRC Licensed Activities

Mallinckrodt has held NRC Radioactive Material License STB-401 (docket number 40-6563), since 1961 for the extraction of C-T from natural and synthetic ores and slags. The license was renewed on March 9, 1989, to allow receipt, possession, and manufacturing of 30,000 kg, each, natural and synthetic uranium and thorium ores. Although C-T process operations were performed in an area called Plant 5 at the Mallinckrodt site, support activities were conducted in portions of Plants 1, 3, 6, 7, and 8. On July 12, 1993, the license was amended to possession-only and reduced the maximum possession quantities to 3,000 kg, each, of natural uranium and natural thorium in any physical or chemical form. License STB-401 was amended on May 3, 2002, (Amendment 3) to incorporate the approved Phase I DP. On May 12, 2008, NRC amended Mallinckrodt's license to authorize removal of unreacted ore (URO) from Plant 6W.

3.2.3 Previous C-T and MED-AEC Decommissioning Activities

C-T Decommissioning Activities

Mallinckrodt submitted the C-T Project Phase 1 DP to NRC on November 20, 1997. NRC approved the Phase 1 DP on May 3, 2002 (ML021230256). During Phase 1, most of the decommissioning activities occurred within Plant 5. However, C-T support areas in Plants 3, 6, and 8 were also addressed. Mallinckrodt's Phase 1 decommissioning activities consisted of:

- removing equipment and services, and demolishing Plant 5 Buildings 213, 214, 238, 246, 247 and 248;
- roof sampling and decontaminating roof and exterior surfaces of Plant 5 Buildings 200, 204, 222, 223, 235, 236, 240, 245, and 250;
- decontaminating and surveying selected interior areas of Plant 5 Building 250;
- surveying Plant 3 Building 62;
- surveying Plant 8 Buildings 90 and 91;
- removing incinerator from pad near Plant 6 Building 101; and
- surveying Plant 6 Building 101 roof.

Mallinckrodt decommissioned the buildings and equipment to the extent necessary to meet the NRC's criteria for unrestricted release. Phase 1 of the decommissioning project was completed in February 2007.

MED-AEC Decommissioning Activities

MED-AEC facilities in Plants 1 and 2 were partially decommissioned in 1950 and 1951. Further decommissioning was performed in the early 1960's. MED-AEC facilities in Plants 4 (now known as Plant 10), 6 and 7 were also decommissioned to the standards of the day in the early 1960's. Decommissioning activity included building decontamination or demolition and removal of some soils and subsurface materials.

FUSRAP was created by the U.S. Congress to identify and control or remediate 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.

The U.S. Department of Energy (DOE), under FUSRAP, had the initial responsibility for remediating radioactive and chemical contamination in the areas of the Mallinckrodt site that formerly housed MED-AEC operations. However, in October 1997, Congress transferred the FUSRAP from DOE to USACE. Under FUSRAP, USACE is responsible for the cleanup of both radioactive and hazardous chemical contamination at the Mallinckrodt site with oversight by the U.S. Environmental Protection Agency (EPA).

USACE is responsible for the remediation of Buildings K, 25, 50, 51, 51A, 52, 52A, 100, 116, 117, 219, 700, 704, 705, 706, 707, and 708 and other areas of the site, including subsurface areas, containing uranium processing residues. USACE has completed decontamination or demolition of all of these structures except Buildings 25 and 100. USACE is currently remediating soils containing subsurface residues from MED/AEC operations.

Some Plant 6 and 7 buildings and adjacent open areas were used to support C-T manufacturing following their decontamination and release to Mallinckrodt by the AEC in the early 1960s. Soils in these areas contain substantial volumes of residues from uranium refining and are therefore, subject to remediation by the USACE under FUSRAP. The USACE will remediate Plant 6 and 7 soils over the next several years.

The USACE will document the locations remediated and post-remediation radionuclide concentrations as part of their project closure activities.

3.2.4 Descriptions of Past Spills and Releases

The DP states that documentation does not describe any accidental spills or releases of radioactive material from 1961 - 1987. Therefore, Mallinckrodt conducted interviews with past and present employees involved in C-T operations to obtain historical information. Based on these interviews, it was determined that, during the operational period of the C-T process site, raffinate tanks located north of Buildings 246 and 247 overflowed on more than one occasion. When the main tanks overflowed, raffinate was diverted to a backup tank. However, in some instances, the backup tank did not contain all of the material.

Material Handling Losses – Various C-T raw material and residue handling operations were performed in process and support buildings and outside areas in Plants 5, 6, and 7. Minor spills occurred on occasion during these activities. Specific information on the types, forms, activities, and concentrations of radionuclides released in spills and similar events is not available. The nature of the materials released would not have differed significantly for those handled under routine operations. Spills and other releases would have occurred in areas where these materials were routinely handled and processed.

3.2.5 On-site Burials

The C-T process generated URO residue that contained materials that were not dissolved in the initial C-T process steps. URO contained natural uranium, natural thorium, and their progeny in addition to nonradioactive constituents. Specific URO composition varied with raw material composition and process conditions.

In 1972 and 1973, approximately 300 cubic yards of drummed URO was buried in ten trenches located in Plant 6. This type of onsite burial is no longer authorized by NRC regulations. Trenches were generally excavated to a depth of six feet (ft). An approximate two-foot thick layer of URO was placed in the trench and compacted. The trench was then

backfilled with compacted excavated soil. A finished goods warehouse (Building 101) was subsequently constructed above one of the trenches.

### 3.3 Facility Description

Chapter 3 of the DP provides detailed descriptions of the site location, the population distribution surrounding the site, current and future land use of the site, and the physical characteristics of the site including climatology, meteorology, geology, seismology, and hydrology. Summaries of the site location, the population distribution surrounding the site, current and future land use of the site, and hydrology were taken from the DP and are provided below.

#### 3.3.1 Site Location and Description

The Mallinckrodt site is a 43-acre [174,016 square meters ($m^2$)] site located near the west bank of the Mississippi River in an area zoned and developed for industrial use. The City of Venice, Illinois is the nearest city on the east bank of the Mississippi River. The plant is generally bounded by Angelrodt Street on the south, Salisbury Street on the north, Broadway Street on the west, and Wharf Street on the east. A small Plant 7E area is located east of Wharf Street. Plant topography is generally flat, with a slight decrease in elevation toward the east. Elevations across the site range from approximately 122 m (400 ft) above mean sea level on the east to approximately 130 m (425 ft) at Broadway Street on the west. Although the site is in the historic flood plain of the Mississippi River, it is protected from flooding by a levee constructed by USACE in 1964 and operated by the City of St. Louis.

#### 3.3.2 Population Distribution

The City of St. Louis population on April 1, 2000 was 348,189. Mallinckrodt is located in census tract 1267 and surrounded on the North, East, South, and West by tracts 1097, 4007, 1266, and 1202, respectively. Tract 4007 is located east of the Mississippi River in Illinois. The 2000 U.S. census reports a total population of 1,997 in tract 1267 and a total of 12,904 in 1267 and surrounding tracts. The total population in these tracts decreased by 29% from 1990-2000.

The 2000 population in census tract 1267 and surrounding tracts was 84% black or African American, 14% white, and 1% other races. Black or African American and other races comprised 70% of the population in tract 1267 and 95%, 94%, 71%, and 86% of the population in census tracts to the north, east, south, and west, respectively.

Projections of population change in the St. Louis area are inconsistent. The state of Missouri projects continued decreases of 9-12% per year in the City of St. Louis population from 2000-2025. The East-West Gateway Coordinating Council predicts an increase of approximately 0.4% per year over the same period.

#### 3.3.3 Current and Future land Use

The Mallinckrodt site is in an urban industrial area. Manufacturing and support buildings cover a large portion of the site, and the remainder of the area is typically paved with asphalt or concrete. Three railroads cross, serve, or are adjacent to the site: Burlington, Northern, and Santa Fe; Norfolk Southern; and the St. Louis Terminal Railroad Association.

The site area is zoned “K” (unrestricted district) by the City of St. Louis. This industrial zone allows all uses except new or converted dwellings. Some uses allowed within this zone under conditional use permit are acid manufacture, petroleum refining, and stockyards. The long-term plans for this area are to retain the industrial uses, encourage the wholesale produce district, and phase out any junkyards, truck storage lots, and the remaining marginal residential uses.

Land use within a 1.6 kilometer (km) [1 mile (mi)] radius of the site reflects a mixture of commercial, industrial, and residential uses.

Property owned by the City of St. Louis is located between Mallinckrodt and the Mississippi River. The Mississippi River levee is located on city property. The Riverfront Trail hiking and bicycle trail runs along the top of the levee, but the property is otherwise undeveloped and unfenced.

3.3.4 Surface Water Hydrology

The site is located on the western bank of the Mississippi River at River Mile 182.5, 20 km (12.7 mi) downstream from the confluence of the Mississippi and Missouri Rivers. The site is approximately 32 km (20 mi) upstream of the confluence of the Mississippi and Meramec Rivers. The Mississippi, Missouri, and Meramec Rivers, 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.

The Mississippi River in the St. Louis area is classified as a Class “P” (permanent flow) waterway. It is a significant commercial waterway and navigable from Minneapolis to the Gulf of Mexico. 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. For this reason, the State of Missouri has issued a fish advisory.

Although flooding has occurred every month of the year, higher flows are frequently associated with snow melt and heavy rains in spring. A levee and floodwall system constructed in 1964 on city property east of the site protects the Mallinckrodt facility from Mississippi River floodwaters. The system is operated by the City of St. Louis and maintained by USACE.

The City of St. Louis operates the metropolitan municipal water system. This system provides all the water required for domestic, industrial, and other uses within the City. The system intake and treatment plant are located upstream of the site and the Bissell Point Plant discharge. The Illinois-American Water Plant is located on the east bank of the Mississippi River approximately 12 km (7.5 mi.) downstream of the site. This plant supplies a small percentage of the water required by the City of East St. Louis. Total consumptive use of Mississippi River water by downstream Missouri and Illinois users during 1990 was approximately 0.5% of the long term average river flow measured at St. Louis. Water resource availability is not an issue of concern.

3.3.5 Ground Water Hydrology

Mallinckrodt, DOE and USACE (under FUSRAP) have extensively studied the subsurface hydrogeologic conditions at the facility. This section presents a summary of the groundwater hydrology of the Mallinckrodt site. A more complete description, including a discussion of

groundwater flow directions and a conceptual hydrogeologic model, is presented Appendix A to the DP.

Two hydrostratigraphic units are recognized above bedrock beneath the facility. The first zone, or the Upper Hydrostratigraphic Zone (upper zone), consists of the surficial fill and the underlying unit of low permeability silts and clays. The second, or Lower Hydrostratigraphic Zone (lower zone), is composed dominantly of sands, silty sands, and gravels. The fine-grained alluvial silt and clay at the base of the upper zone acts as a relatively impermeable barrier between the surficial fill in the upper zone and the relatively permeable alluvium in the lower zone.

The surficial fill material is 2-6 m (7-18 ft) thick beneath Plant 5 and up to 7.6 m (25 ft) thick elsewhere beneath the St. Louis Downtown Site. The fill extends slightly beyond Broadway Street west of the site, east to the Mississippi River, and north and south of the site for a significant distance. Perched groundwater occurs within the fill at depths ranging from 1-3 m (6-9 ft) below ground surface. The fine-grained alluvial silt and clay below the fill is 6-11 m (18-37 ft) thick and extends to the west to approximately Broadway Street, east to the Mississippi River, and north and south of the site for a significant distance.

The lower zone is 0-2 m (0-7 ft) thick beneath Plant 5 and up to 15 m (50 ft) thick elsewhere at the site. The unit thickens eastward towards the Mississippi River and extends north and south of the site. The groundwater potentiometer surface in the lower zone occurs at depths of approximately 3-10 m (10-35 ft) below ground surface. Groundwater in the lower zone is in hydraulic communication with the Mississippi River. Groundwater flow in the lower zone is generally towards the river during low river stage and away from the river during high river stage.

The limestone bedrock surface beneath Plant 5 occurs at depths ranging from 10-16.5 m (32-54 ft) and slopes towards the Mississippi River where it is found at a depth of approximately 24 m (80 ft). Bedrock is recharged from up-gradient areas and discharges to the Mississippi River.

### 3.4 Radiological Status of the Facility

NRC staff has reviewed the information in the “Facility Radiological Status” section of the DP, and has determined that Mallinckrodt has described the types and activity of radioactive material contamination at its facility sufficiently to allow the NRC staff to evaluate the potential safety issues associated with remediating the facility, whether the remediation activities and radiation control measures proposed by the licensee are appropriate for the type of radioactive material present at the facility, whether the licensee’s waste management practices are appropriate, and whether the licensee’s cost estimates are plausible, given the amount of contaminated material that will need to be removed or remediated.

#### 3.4.1 Contaminated Systems and Equipment

Contaminated structures were addressed during Phase 1 and therefore are not within the scope of the Phase 2 DP. Systems and Equipment to be addressed during Phase 2 include the utility systems used to support operations at the site. These utilities are water, electric, gas, sewer, and communications. The utilities, with the exception of sewer, will be relocated or worked around as necessary to facilitate remediation of surrounding contaminated soil.

Characterization studies indicate that portions of the Plant 5 sewer system have radiological constituents in concentrations greater than the proposed release limits or site specific derived concentration guideline levels (DCGLs). The DCGL's are described further in Section 3.13 of this SER.

Samples from manholes indicate that the contaminated sewer line is confined to segments immediately southwest, west, and north of Building 238.

3.4.2 Pavement and Building Slabs

Direct survey results and scabble samples from the characterization studies indicate that almost all of the pavement of Plant 5 may be released for unrestricted use. Three of the 1670 measurement results exceeded the proposed DCGL release limit.

An area of pavement on the south and west sides of Building 238 is potentially contaminated and will be designated as NUREG 1575, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) Class 2 survey unit. If this area of pavement were subject to removal or decontamination, the volume to be removed would be about 8200 $ft^2$ x 0.5 ft thick.

In addition to the pavement around Building 238, floor slabs of Buildings 213, 213A, 213B, 214, 238, 246, 246B, 247, 247A, 247B, and 248 are potentially contaminated. The combined area of process and support building floor slabs equals 25000 $ft^2$. The total volume of the slabs is estimated to be 13000 $ft^3$.

3.4.3 Subsurface Material

Characterization studies indicate that some soils in the Plant 5 area contain radionuclide concentrations exceeding the proposed DCGL release limits. The estimated volume of the contaminated subsurface soil expected to exceed DCGL is approximately 42,000 $ft^3$. Approximately 70,300 $ft^3$ of unreacted C-T ore buried in 10 burial pits in Plant 6W is being excavated under License Amendment 4 which was approved on May 12, 2008 (ML080940414). Contaminated subsurface material located in Plant 7 will be addressed during Phase 2 but only after an agreement on delineation of responsibility between Mallinckrodt and USACE is reached.

3.4.4 Surface Water

The only surface water in the area is the Mississippi River, adjacent the east side of the plant site. The river flow and site drainage characteristics are described in Section 3 of the DP. Due to the large flow volume of the Mississippi River and the environmental controls established for the site, no detectable impacts are expected to surface water from decommissioning activities.

3.4.5 Ground Water

Total uranium, radium-226, and thorium-230 were analyzed in samples collected from eight monitoring wells during four quarterly sampling events between July 1988 and April 1989 (USACE, 1998). The groundwater was sampled again during a single event in late 1997/early 1998 that included 17 monitoring wells. Samples were analyzed for actinium-227, lead-210, protactinium-231, radium-226, radium-228, thorium-228, thorium-230, thorium-232,

and total uranium. Summary data are presented in Appendix A of the DP. Total uranium was the only radionuclide detected in filtered samples at concentrations above background levels. The elevated concentrations were detected in only a single well, B16W02S, which is screened in perched groundwater in the upper zone in Plant 1. The total uranium concentrations in this well have ranged from a 1988/1989 average of 228 micrograms per liter (µg/l) to a 1997/1998 value of 1,187 µg/l. This does not present a groundwater ingestion hazard since the perched groundwater in the upper zone is not a drinking water source. Although protactinium-231 was detected at concentrations up to 45 picocuries per liter (pCi/l) in unfiltered groundwater samples from three wells (none in the C-T process areas), it was not detected in filtered samples from these three wells. USACE has concluded, and the NRC staff sees no reason to disagree, that the protactinium is bound to sediment particles and that the unfiltered results are not representative of groundwater quality at the site. No radionuclides were detected above EPA maximum concentration limits (MCLs) in filtered groundwater samples from the lower zone. This finding suggests that the low-permeability silt and clay layers between the upper and lower zones retard contaminant migration between the two zones.

3.5 Dose Analysis

The staff has independently assessed the dose modeling analyses for unrestricted release as part of the review of Mallinckrodt's DP, in accordance with the Consolidated Decommissioning Guidance, NUREG-1757, Volume 2, Section 5.2 (Unrestricted Release Using Site-Specific Information). The staff concludes that the dose modeling analysis is reasonable and is appropriate for the industrial use exposure scenario. In addition, the dose estimate provides reasonable assurance that the dose to the average member of the critical group (an industrial worker) is not likely to exceed the 25 millirem (mrem) annual dose criterion in 10 CFR 20.1402. This conclusion is based on the modeling effort performed by the licensee and the independent analysis performed by the staff (ML091831289).

The staff evaluated the licensee's proposed critical group, land use scenario, and set of pathways used in the dose assessment and find them acceptable. In addition, the staff finds that an appropriate conceptual model was used in RESRAD and input parameters were used in the development of the DCGL values for soil and pavement The licensee has adequately considered the uncertainties inherent in the modeling analysis.

Section 7 of the DP provides an analysis which demonstrates that the site specific DCGLs developed for the proposed decommissioning activities are As Low As Reasonably Achievable (ALARA). Consistent with the guidance in NUREG-1757, Section 5.2, the staff has reviewed the analysis, and considered the detriments expected to potentially result from decontamination and waste disposal (i.e., deaths from transportation accidents) provided by the licensee and find them to be complete. Based on this analysis the staff has determined that the DCGLs are ALARA.

3.6 Planned Decommissioning Activities

The NRC staff has reviewed the decommissioning activities described in the DP according to the Consolidated Decommissioning Guidance, Volume 1, Section 17.1 (Planned Decommissioning Activities). Based on this review the NRC staff has determined that Mallinckrodt has provided sufficient information to allow the NRC staff to evaluate the licensee's planned decommissioning activities to ensure that the decommissioning can be conducted in accordance with NRC requirements.

Mallinckrodt's general decommissioning approach and planned decommissioning activities are described in Sections 3.6.1 thru 3.6.7 below.

3.6.1 Approach to Decommissioning

Most of the Phase 2 decommissioning activities will occur in Plant 5. However, the former wastewater neutralization basins located in Plant 7W will also require decommissioning.

Mallinckrodt will continue to engage in non-NRC licensed manufacturing activities while decontamination and remediation are performed. Mallinckrodt selected the following decommissioning strategy: remediate remaining floor slabs and subsurface soils and systems by decontamination or excavation and disposal followed by a final survey; remediate former wastewater neutralization basins by decontamination or demolition and disposal followed by final surveys where appropriate; and remediate sewerage.

Mallinckrodt and its contractor(s) will determine whether decontamination and final status survey (FSS) of materials is preferred over excavation and offsite disposal. The Phase 2 DP is based on the following preferences: 1) excavation or demolition and disposal offsite when it is cost-effective; 2) decontamination when it is judged to be cost-effective compared to disposal; and 3) decontamination or removal of selected contaminated areas of pavement and subsurface material to < DCGL, to reduce the waste volume and therefore minimize the cost of disposal.

Mallinckrodt's general technical approach for decommissioning is: 1) decontamination, if necessary, or removal of remaining C-T building floor slabs and foundations; 2) removal or plugging of contaminated sewers and soils; 3) packaging and shipping of contaminated materials for transfer to an appropriate facility; 4) final radiation status survey; 5) backfilling and compaction of remediated areas; and 6) final grading and paving.

Sewer decontamination and/or excavation will be performed in accordance with administrative controls and programs that were used successfully for Phase 1 decommissioning activities. Pertinent procedures developed for Phase 1 decommissioning activities will be used during Phase 2, with appropriate revisions.

Water misting or similarly effective dust control methods will be used as necessary to prevent the release of airborne dust during excavation and materials handling activities.

Surveying, decontamination, excavation, and removal of drains and subsurface sewerage do not entail unique construction or remediation safety issues. Mallinckrodt has safely and effectively performed such activities during routine operations and maintenance of the facility, and Phase 1 decommissioning activities. Given Mallinckrodt's experience, the staff concludes that Mallinckrodt can safely perform these activities during Phase 2.

3.6.2 Street Pavement

Streets in Plant 5 are paved with macadam or concrete. In compliance with the Phase I DP, some pavement was covered with a seal-coat of macadam. The seal-coat will be removed to permit accurate survey of the pavement. Seal-coat debris will be confirmed to be contamination-free by bulk survey before disposal in an industrial waste landfill or recycling in ready-mix asphalt pavement.

3.6.3 Building Slabs and Foundations

In compliance with the Phase I DP, building slabs in Plant 5 were covered with a seal-coat of macadam following demolition. The seal-coat will be removed to permit accurate survey of the slabs. C-T process and support building floor slab and foundation surfaces exposed above grade that are subject to decommissioning include Buildings 213, 213A, 213B, 214, 238, 246, 246B, 247A, 247B, and 248. Floor slabs or foundation surfaces requiring remediation will either be decontaminated, e.g., by scabbling, or will be removed. In the event a floor slab or foundation is removed, its debris will be characterized for disposal and will be managed in accordance with the radioactive waste management program.

If access to contaminated subsurface soil is necessary, pavement or floor slabs will be removed. If contaminated soil is not present beneath pavement or floor slabs, they may be left in place. Where gross removal is necessary, it will be completed using standard construction equipment such as excavators, bulldozers, front-end loaders, dump trucks, compactors, water trucks, fork-trucks, and miscellaneous small tools. Debris size reduction will be performed during excavation as required for transportation and disposal. Excavated pavement and associated soil and debris will either be loaded into shipping containers at the excavation site or will be transported to the soil handling area for characterization, segregation, staging and shipment.

3.6.4 Wastewater Neutralization Basins

The former wastewater neutralization basins in Plant 7W will either be removed and disposed by NRC-authorized transfer to a disposal facility or be decontaminated (if necessary) and left in place. If the basins are left in place, Mallinckrodt will demonstrate via FSSs that the basins are suitable for unrestricted release. The wastewater neutralization basins and surrounding areas will be remediated, as necessary, using the following steps:

- basin liners will be removed and packaged for shipment and disposal;
- exposed concrete surfaces will be surveyed either for the purpose of establishing cost-effective disposal or final radiation status to compare with DCGL; and
- exposed surfaces of concrete structures may be decontaminated, as appropriate, by scabbling, grit blasting or similar techniques, or broken into appropriate size pieces for disposal, and loaded into transport containers using conventional demolition equipment and techniques.

The former wastewater neutralization basins in Plant 7W are contaminated with material from C-T process activities and MED-AEC activities. Mallinckrodt and USACE have not yet determined responsibility for the residual radioactive material located in Plant 7W. Decommissioning of the wastewater neutralization basins will proceed after Mallinckrodt and USACE prepare a delineation agreement defining responsibility for areas of residual radioactive contamination. The agreement must be approved by NRC.

3.6.5 Sewerage Systems

3.6.5.1 Drains and Subsurface Sewerage That Served C-T Process Buildings

Drains and sewers that served C-T process buildings are the most likely to contain residues of licensed radioactive material. Interpretation of the manhole samples indicates radioactive contamination in sewerage to be confined to segments immediately southwest, west, and north of Building 238. Drains and sewerage that served C-T process buildings (238, 246B,

247A&B, 248) will either be plugged to prevent use or will be removed during removal of building floor slabs and shallow soil, if any.

Main sewer lines immediately to the west and north of Building 238 will be removed or plugged in the process of remediation of subsurface soils beneath Building 238. If they are removed, the sewers and the sludge in them will be treated as radioactive waste. If plugged, the sewer line may be released for unrestricted use if warranted by a FSS as described in Section 14 of the DP. It is anticipated that sewers remaining downstream of Building 238, beginning at the west end of Buildings 236 and 245 and extending to the Waste Water Treatment Basin area, will remain in service after FSS and released for unrestricted use.

The sewer line involved is made of clay or concrete, is buried, and would be impractical to salvage intact. If future excavation were to intrude into it or even intend to remove it, it would likely be broken into debris during excavation. While being excavated and brought to the surface, the debris and nearby excavate would be expected to be mixed as excavation spoil. This is equivalent to the scenario in which inadvertently excavated subsurface soil would be mixed as excavation progresses from land surface downward, and the resulting mixture average concentration would be compared with the DCGLw derived for topsoil. Thus, the appropriate scenario and model on which to derive the DCGLw would be the same as for soil. Figure 4.1 of the DP shows the location of manhole samples and sewer lines.

To plug a drain, a contractor would access the drain or sewer via the drain opening, storm drain opening, or manhole into the sewer. In a manner similar to grouting a well to plug it, the contractor would pump cement or a cement-bentonite mixture into the drain or sewer to plug it at these strategic segments to preclude further use and to preclude further drainage of wastewater in the line. Issues pertinent to how occupational dose requirements will be met are discussed below in SER Section 3.8.1.

Objectives of plugging sewerage would be to prevent future use, to contain sediment that might be in it, and to prevent backflow from sewers remaining in use downstream, especially at the juncture of a sewer line upstream to be removed. If sewerage north and west of Building 238 is to be removed, the juncture in sewerage will be plugged, before the sewer line upstream of the plug will be removed in order that sewerage downstream may remain in use. Any sewerage north and west of Building 238 to be plugged rather than removed would be plugged at strategic points before excavation to remove connected sewer lines in order to prevent backflow from downstream. FSS of sewerage downstream remaining in use would be done after plugging upstream and after building slab, foundation, and soil remediation.

3.6.5.2 Drains and Subsurface Sewerage That Served C-T Support Buildings

Mallinckrodt does not anticipate that drains and subsurface sewerage that served C-T support buildings will contain C-T related contamination in excess of the DCGLs. Access points, including such drains, traps, and other at-grade locations that may have been exposed to C-T materials will be identified and surveyed for radioactivity. If these surveys identify contamination, interior surveys, i.e., sediment sampling, will be performed. The access points, sampling locations, and survey findings will be recorded. If surveys in access points do not identify the presence of radioactivity above criteria, the licensee assumes that downstream sewerage will also have radioactivity levels less than the release criteria, and would not survey such downstream areas. Given the nature of the expected contamination, the staff agrees that if contamination from C-T material exists above the DCGLs, it will be found in locations such as traps and drains. Further, the staff agrees that if surveys of access points, traps, and drains close to the contamination source produce acceptable

results, it is unlikely that higher concentrations would occur in areas downstream because the material will settle in the lowest point closest to the contamination source.

3.6.5.3 Drains and Subsurface Sewerage That Served C-T Yard Areas

Drains and subsurface sewerage that served C-T yard areas will be addressed in a manner similar to that employed for drains and subsurface sewerage that served C-T support buildings.

3.6.5.4 Plant 7 Lift Station

The Plant 7 Neutralization basin lift station interior surfaces will be surveyed for radioactivity contamination, including any exposed joints. Areas exceeding the DCGL for pavement will be decontaminated using scabbling, grit blasting, or other techniques, or will be removed.

3.6.5.5 Sewerage That Served MED/AEC Operations

USACE is addressing sewerage serving MED/AEC operations under the FUSRAP program, including sewerage that may contain commingled C-T residue. Those sewers are not within the scope of the DP.

3.6.5.6 Sewerage That Served Neither C-T Nor MED/AEC Operations

The licensee states that no decommissioning activity will be performed in sewers that served neither C-T nor MED/AEC operations as they cannot reasonably be expected to contain C-T contamination in excess of criteria. The staff agrees that such sewers are reasonably assumed as being unimpacted by C-T contamination, and that the expense of performing confirmatory surveys in such areas would not be justified.

3.6.6 Soil

Characterization data indicate that radioactive residue in some soils beneath and adjacent to C-T process Building 238 exceeds the DCGL. Soil remediation will generally be performed as follows:

- three-dimensional modeling of characterization data will define the gross outline of areas exceeding the soil DCGL;
- the areas where the DCGL is exceeded will be excavated using conventional construction equipment;
- radiation measurements will be employed to guide remedial excavation;
- excavated soils will be loaded into trucks or containers at the site of remediation and moved to the material handling area or shipped in accordance with NRC-authorized transfer to a state-regulated disposal facility;
- a FSS will be performed in each remediated area;
- excavated soil demonstrated to contain lower radioactivity concentration than the DCGL may be returned into an excavation pit; and
- remediated areas will be backfilled, compacted, graded, and resurfaced, as appropriate.

In the event groundwater prevents direct access to survey the bottom of an excavation cavity, an alternative would be to backfill as much as one meter and do final status core sampling through the backfill into the unexcavated bottom. Adjacent land not requiring excavation in

the same survey unit will be subject to soil core sampling and analysis to complement the FSS.

Mallinckrodt and USACE have not yet finalized an agreement delineating responsibility for soil beneath the former wastewater neutralization basins in Plant 7W. Mallinckrodt's license will be amended to state that Mallinckrodt must receive NRC approval of the Plant 7W delineation agreement before conducting any remediation activities in that area.

3.6.7 Ground Water

No groundwater remediation is anticipated below C-T process areas because: (1) there is no evidence that radiological contamination exists below C-T process areas; and (2) there is no groundwater exposure pathway at the site.

Groundwater monitoring has been performed at the site by Mallinckrodt, DOE and USACE and is described in Appendix A of the DP. Based on the site well monitoring data, there is no evidence that radiological contamination exists in the ground water beneath the C-T process areas. As stated in Section 3.4.5 of this SER, total uranium was the only radionuclide detected in filtered samples at elevated concentrations at the Mallinckrodt site. The elevated concentrations were detected in only a single well, B16W02S, which is screened in perched groundwater in the upper zone in Plant 1, which is not a C-T process area and is being remediated by USACE under FUSRAP. The total uranium concentrations in this well have ranged from a 1988/1989 average of 228 µg/l to a 1997/1998 value of 1,187 µg/l. These levels are not a groundwater ingestion hazard because the perched groundwater in the upper zone is not a drinking water source.

Although protactinium-231 was detected at concentrations up to 45 pCi/l in unfiltered groundwater samples from three wells (none in C-T process areas), it was not detected in filtered samples from these three wells. USACE has concluded that the protactinium is bound to sediment particles and that the unfiltered results are not representative of groundwater quality at the site. No radionuclides were detected above EPA MCLs in filtered groundwater samples from the lower zone within the Mallinckrodt site boundary.

Mallinckrodt will monitor water in the C-T process areas for radionuclide contamination as part of waste handling process. Water collected in excavations during remediation, either from runoff or groundwater, will be collected, sampled and discharged in accordance with 10 CFR 20.2003 and Mallinckrodt's Metropolitan St. Louis Sewer District discharge permit. Mallinckrodt will be required, by license condition, to notify NRC if filtered water samples contain radionuclides exceeding the EPA MCLs.

There is not a complete groundwater exposure pathway at the site. As stated in Section 3.5 of this SER, the staff concludes that an industrial use exposure scenario, without a ground water exposure pathway, is appropriate for the C-T process areas. The groundwater beneath the site is not a current source of drinking water, nor will it likely be a source of drinking water in the future. As indicated previously, the City of St. Louis operates and maintains a municipal water system and there are no groundwater withdrawal wells in the site vicinity. Furthermore, a City ordinance prohibits installation of drinking water wells in areas such as the Mallinckrodt site, and groundwater discharges to the Mississippi River immediately downgradient of the site.

## 3.7 Project Management and Organization

The NRC staff has reviewed the description of the decommissioning project management organization, position descriptions, management and safety position qualification requirements and the manner in which Mallinckrodt will use contractors during the decommissioning of its facility. Based on this review, the NRC staff has determined that Mallinckrodt has provided sufficient information to allow the NRC staff to evaluate the licensee's decommissioning project management organization and structure to determine if the decommissioning can be conducted safely and in accordance with NRC requirements.

(Note that this finding incorporates the results of the staff's assessment under Sections 3.7.1–3.7.5, below.)

### 3.7.1 Decommissioning Management Organization

Section 9 of the DP states that implementation of the DP will be managed by a team comprised of management, radiation safety, and occupational safety personnel from the Mallinckrodt and decommissioning contractor organizations. Although contractors will be involved in decommissioning activities Mallinckrodt will retain overall responsibility for implementation of the DP.

Mallinckrodt will use a contractor to develop and/or implement the radiological safety, occupational safety, and environmental protection programs and the procedures required by the DP. The contractor will provide the equipment, materials, and a trained and experienced labor force to perform the decommissioning activities. The contractor will also provide an independent quality assurance program as required by the DP.

### 3.7.2 Decommissioning Task Management

Mallinckrodt will use various project management (PM) and decommissioning consultants to assist in the management of decommissioning activities. These persons and/or organizations take their direction from the Mallinckrodt PM.

Decommissioning activities for the C-T Project will be performed in accordance with written instructions. There will be four general types of written instructions in use for the C-T Project: plans, procedures, work plans, and Safety Work Permits (e.g., Hot Work Permits, Excavation Permits, etc.).

### 3.7.3 Decommissioning Management Positions and Qualifications

The DP states that the Mallinckrodt C-T PM is responsible for ensuring that the overall C-T decommissioning project, including the work performed by contractors and subcontractors, is accomplished in conformance the DP and with applicable health, safety, quality, technical, and contractual requirements. The PM is also responsible for assuring that NRC requirements are met. The PM has full authority to halt any operation that he or she believes has the potential to threaten the health and safety of site or contractor personnel, the public, or the environment, is not in conformance with the DP, or is otherwise not meeting NRC requirements.

Section 9.3 of the DP describes the qualifications necessary for Mallinckrodt and contractor management personnel.

3.7.4 Training

Section 9.4 of the DP provides the training requirements for all workers performing decommissioning activities. It states that all decommissioning personnel will be required to complete Mallinckrodt site-wide industrial safety training program. In addition, Mallinckrodt has committed to the following training:

- construction workers performing decommissioning activities will be trained as radiation workers commensurate with the radiological dose and risk estimated and observed.
- C-T Project personnel will be trained to perform their assigned responsibilities safely. On-the-job training and equipment-specific training will supplement the Mallinckrodt site-wide training program. Training in the proper use of specialized equipment is given before the person uses that equipment.
- all unescorted persons involved in decommissioning activities will be required to complete the Mallinckrodt radiation safety training course or the contractor equivalent course.
- each person will be trained before entering a controlled area to perform work. The safety performance of each person will be reviewed annually, and workers will be retrained every two years.

3.8 Health and Safety Program

Mallinckrodt has committed to perform decommissioning activities in accordance with a Health and Safety Program (HSP), which will include: (1) an Industrial Safety Program; (2) a Radiation Protection Program (RPP); and, (3) an Environmental Safety Program (ESP). Although a detailed Health and Safety Program has not yet been developed, the DP provides the minimum requirements for each element of the program. Implementation of the HSP will be evaluated during NRC site inspections.

The RPP will include procedures to protect workers and the public from ionizing radiation and keep exposures to radiation “as low as reasonably achievable” (ALARA). Mallinckrodt has stated that the remediation contractor will be required to implement a Radiation Safety Program which incorporates the following elements from Section 3.3 of the DP:

- health and safety protection measures and policies;
- instrumentation, calibration and equipment;
- use of air samplers, monitoring policy methods, frequency and procedures;
- contamination control and personnel decontamination;
- external exposure control;
- airborne releases and monitoring;
- Radiation Safety Work Permits;
- engineering controls;
- transportation;
- accident response;
- posting and labeling;
- records and reports;
- potential sources of contamination exposure; and
- ALARA.

The DP states that Mallinckrodt will be responsible for overall project direction and ensuring that NRC requirements are met. The remediation contractors will be responsible for

implementation of the radiological, occupational, environmental safety and quality assurance programs. The contractors will also be responsible for providing trained personnel to conduct decommissioning activities.

### 3.8.1 Radiation Safety Controls and Monitoring for Workers

#### 3.8.1.1 Workplace Air Sampling Program

Section 10.1.1 of the DP describes the workplace air sampling program. In the DP, Mallinckrodt commits to conduct an air sampling program during decommissioning in accordance with, or equivalent to, the guidance provided in the NRC Regulatory Guide 8.25, "Air Sampling in the Workplace", July 1992. Breathing zone air samples will be the primary method of monitoring the worker's intake of radioactive material. The samples will be collected under known physical conditions (e.g., filter type, sample time, flow rate). The flow meters of air samplers shall be calibrated at least annually. Calibration shall also be performed after repair or modification of the flow meter.

Air samples will also be collected of general and localized areas when and/or where there is potential for generation of airborne radioactive material. These samples will be used to verify that the confinement of radioactive material is effective and provide warning of elevated concentrations for planning or response actions. In each case, the sampling point will be located in the airflow pathway near the known or suspected release point(s). As necessary, more than one air sample location may be used in order to provide a reasonable estimate of the general concentration of radioactive material in air.

Mallinckrodt has established an administrative action level for breathing zone air samples of one derived air concentration (DAC); air sample results greater than this administrative action level shall be reported to the HSP Manager or the radiation safety officer (RSO). In the event airborne radioactivity concentration is > 1 DAC or likely to be more than 12 DAC·hr in a week, the area shall be posted as an airborne radioactivity area with wording "Caution, Airborne Radioactivity Area" or "Danger, Airborne Radioactivity Area." Mallinckrodt has also established an administrative limit for breathing zone air samples of 10 DAC-hours Individual exposures greater than this action level shall require the individual to be restricted from work involving potential exposure to airborne radioactive material unless approved by the Site RSO.

The NRC staff has reviewed Section 10.1.1 in the DP in accordance with the Consolidated Decommissioning Guidance, Volume 1, Section 17.3.1.1 (Workplace Air Sampling Program). Based on this review, the NRC staff has determined that Mallinckrodt has provided sufficient information on when air samples will be taken in work areas, the types of air sample equipment to be used and where they will be located in work areas, calibration of flow meters, minimum detectable activities of equipment to be used for analyses of radionuclides collected during air sampling, action levels for airborne radioactivity (and corrective actions to be taken when these levels are exceeded) to allow the NRC staff to conclude that the licensee's air sampling program will comply with 10 CFR 20.1204, 20.1501(a)–(b), 20.1502(b), 20.1703(a)(3)(i)–(ii), and Regulatory Guide 8.25.

#### 3.8.1.2 Respiratory Protection Program

Section 10.1.2 of the DP describes the RPP. The use of respiratory protection is not anticipated to be necessary during C-T Phase 2 decommissioning activities. The RPP provides guidance and instruction regarding protection of workers from occupational injury

and illness due to exposure to airborne radioactive material. The RPP is implemented by written procedures. The RPP and implementing procedures are the primary means used to administratively establish safe respiratory protection practices and compliance with requirements of the NRC.

The RPP covers routine use of respiratory protection equipment. The functional areas of the RPP include medical evaluation, fit testing, selection, issue, inspection, cleaning, maintenance, storage, and training. The RPP incorporates specifications for respiratory protection in 10 CFR Part 20, Subpart H, to guide preparation of procedures implementing a respiratory protection program.

All workers required to wear respiratory protection equipment shall be required to successfully complete a fit test prior to initial use of the equipment. The fit test shall be repeated at least annually. A worker shall not be allowed to wear a respirator without a current successful fit test.

The NRC staff has reviewed Section 10.1.2 in the DP in accordance with the Consolidated Decommissioning Guidance, Volume 1, Section 17.3.1.2 (Respiratory Protection Program). Based on this review, the NRC staff has determined that Mallinckrodt has provided sufficient information to implement an acceptable RPP and to allow the NRC staff to conclude that the licensee's program will comply with 10 CFR 20.1101(b), and 10 CFR 20.1701 to 20.1704 and Appendix A of 10 CFR Part 20.

3.8.1.3 Internal Exposure Determination

Section 10.1.3 of the DP describes the process for determining internal exposure to workers. Mallinckrodt has committed to providing individual monitoring for workers who require monitoring of the intake of radioactive material pursuant to 10 CFR 20.1502(b). Monitoring of intake shall normally be conducted by use of air samples, particularly of the breathing zone. Internal dose shall be determined by converting airborne concentrations to intakes in accordance with NRC Regulatory Guide 8.34 "Monitoring Criteria and Methods to Calculate Occupational Radiation Doses", July 1992.

When a potential or actual condition exists where the worker(s) could have received an unmonitored intake of radioactive material, and cannot otherwise be estimated, the intake shall be determined by measurements of quantities of radionuclides excreted from or retained in the body. These measurements shall be made consistent with the guidance provided in NRC Regulatory Guide 8.9 "Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program", July 1993.

Determination of radiation dose to the embryo/fetus shall be performed in accordance with NRC Regulatory Guide 8.36 "Radiation Dose to the Embryo/Fetus", July 1992.

Work restrictions shall be implemented for any worker with an intake in excess of 50% of the applicable limit in 10 CFR 20.

The NRC staff has reviewed Section 10.1.3 in the DP in accordance with the Consolidated Decommissioning Guidance, Volume 1, Section 17.3.1.3 (Internal Exposure Determination). Based on this review, the NRC staff has determined that Mallinckrodt has provided sufficient information on methods to calculate internal dose of a worker based upon measurements from air samples or bioassay samples to allow the NRC staff to conclude that the licensee's

program to determine internal exposure will comply with 10 CFR 20.1101(b), 20.1201(a)(1), (d) and (e), 20.1204 and 20.1502(b).

3.8.1.4 External Exposure Determination

Section 10.1.4 of the DP describes the process for determining external exposure to workers. Mallinckrodt has committed to provide an individual monitoring device to each worker who requires monitoring for external exposure pursuant to 10 CFR 10.1502(a). External monitoring will be conducted in accordance with or equivalent to NRC Regulatory Guide 8.34, "Monitoring Criteria and Methods to Calculate Occupational Radiation Doses", July 1992.

External exposure monitoring, when required, shall be accomplished using a thermoluminescent dosimeter or optically-stimulated luminescence dosimeter worn on the front of the upper torso. Radiological surveys may be performed to supplement personnel monitoring when work is being performed where workers are required to be monitored.

Mallinckrodt will process dosimeters at least quarterly by a vendor accredited by the U.S. National Institute of Standards and Technology (NIST) National Voluntary Laboratory Accreditation Program (NVLAP). Work restrictions shall be implemented for any worker reaching 50% of the annual limits of 10 CFR 20.

The NRC staff has reviewed Section 10.1.4 in the DP according to the Consolidated Decommissioning Guidance, Volume 1, Section 17.3.1.4 (External Exposure Determination). Based upon this review, the NRC staff has determined that Mallinckrodt has provided sufficient information on methods to measure or calculate the external dose to a worker to allow the NRC staff to conclude that the licensee's program to determine external exposure will comply with the requirements of 10 CFR 20.1101(b), 20.1201(c), 20.1203, 20.1501(a)(2)(i) and (c), 20.1502(a), and 20.1601.

3.8.1.5 Summation of Internal and External Exposures

Section 10.1.5 of the DP describes the process for calculating the total organ dose equivalent and total effective dose equivalent to workers for which monitoring is required. Mallinckrodt has committed to calculate the sum of internal and external doses in accordance with NRC Regulatory Guide 8.34 "Monitoring Criteria and Methods to Calculate Occupational Radiation Doses", July 1992.

The NRC staff has reviewed Section 10.1.5 in the DP according to the Consolidated Decommissioning Guidance, Volume 1, Section 17.3.1.5 (Summation of Internal and External Exposures). Based on this review, the NRC staff has determined that Mallinckrodt has provided sufficient information to conclude that the licensee's program for summation of internal and external exposures will comply with 10 CFR 20.1202 and 20.1208(c)(1) and (2), and 20.2106.

3.8.1.6 Contamination Control Program

Section 10.1.6 of the DP describes Mallinckrodt's contamination control program. Contamination control shall be managed by exposure control and monitored by radiation surveys. Personnel exposure to radioactive material will be controlled by application of engineering, administrative, and personnel protection provisions.

Personal protective equipment will be used to control personnel exposure to radioactive material when administrative controls are not sufficient and engineering controls are not practicable. Personal protective equipment may include head covering, eye protection, respiratory protection, impervious outerwear, gloves, and/or protective shoes or shoe covers.

The NRC staff has reviewed Section 10.1.6 in the DP according to the Consolidated Decommissioning Guidance, Volume 1, Section 17.3.1.6 (Contamination Control Program). Based on this review, the NRC staff has determined that Mallinckrodt has provided sufficient information to control contamination on skin, on protective and personal clothing, on fixed and removable contamination on work surfaces, on transport vehicles, on equipment (including ventilation hoods), and on packages to allow the NRC staff to conclude that the licensee's contamination control program will comply with 20.1501(a), 20.1702, 20.1906 (b), (d), and (f) of 10 CFR Part 20.

3.8.1.7 Instrumentation Program

Section 10.1.7 of the DP describes Mallinckrodt's Instrumentation Program for personnel monitoring. The DP states that instrumentation utilized for personnel monitoring will be calibrated and maintained in accordance with radiation safety procedures. Instrument calibration will be performed by the manufacturer, or by a contractor subject to equivalent calibration requirements. Portable instruments are calibrated on a semi-annual basis or as required due to maintenance. Specific requirements for instrumentation include traceability to NIST standards, field checks for operability, background radioactivity checks, operation of instruments within established environmental bounds (i.e., temperature and pressure), training of individuals, scheduled performance checks, calibration with isotopes with energies similar to those to be measured, quality assurance tests, data review, and record keeping. Where applicable, activities of sources utilized for calibration are also corrected for decay. All calibration and source check records are completed, reviewed, signed off and retained in accordance with Quality Assurance Program (QAP) requirements.

The NRC staff has reviewed Section 10.1.7 in the DP according to the Consolidated Decommissioning Guidance, Volume 1, Section 17.3.1.7 (Instrumentation Program). Based on this review, the NRC staff has determined that Mallinckrodt has provided sufficient information on the sensitivity and the calibration of instruments and equipment to be used to make quantitative measurements of ionizing radiation during surveys to allow the NRC staff to conclude that the licensee's instrumentation program will comply with 10 CFR 20.1501(b) and (c).

3.9 Health Physics Audits and Recordkeeping Program

Section 10.3 of the DP describes health physics audit and recordkeeping requirements for decommissioning. Mallinckrodt states that the radiation safety program will be subject to an annual audit and periodic inspections. The audits and inspections will be performed to determine whether radiological safety activities are conducted in accordance with regulations, license conditions, and written procedures. The audit of the radiation safety program will be conducted annually. The audit shall be conducted by the Site RSO or designee. The audit will consider the basic functional areas of the radiation safety program; e.g., Safety Work Permits, radiation safety procedures, radiological surveys and air monitoring, ALARA emphasis, individual and area monitoring results, access controls, respiratory protection program, training, etc.

The audit will be conducted in accordance with a specific audit plan developed by the auditor. A written report will be generated upon completion of the audit describing the results and the report will be distributed to site management. As necessary, a written corrective action plan will be prepared to address non-compliance issues. All corrective actions will be tracked to completion. Once corrective actions have been completed, a written closure report will be distributed to management documenting the completion of corrective actions.

Periodic inspections will be conducted by the Contractor. These inspections shall be routine reviews performed of operations and activities. The inspections shall be completed against a pre-established checklist. Checklists may be developed independently for differing periods; e.g. daily, weekly, monthly, etc. The checklist items shall be comprised of routine procedural requirements. Any findings discovered during the routine inspection shall be recorded on a tracking log maintained by the Contractor. The log will include a description of planned corrective action and date of completion of corrective action.

The NRC staff has reviewed the description of Mallinckrodt's audit and recordkeeping program which the licensee will utilize during the decommissioning according to the Consolidated Decommissioning Guidance, Volume 1, Section 17.3.3 (Health Physics Audits, Inspections, and Recordkeeping Program). Based on this review, the NRC staff has determined that Mallinckrodt has provided sufficient information to allow the NRC staff to evaluate the licensee's executive management and RSO audit and recordkeeping program to determine if the decommissioning can be conducted safely and in accordance with NRC requirements.

### 3.10 Environmental Monitoring and Control Program

Section 11 of the DP describes a general ESP program to monitor environmental radiation, air effluent, and water effluent discharged from the C-T decommissioning project. The ESP specifies acceptable criteria for environmental monitoring. Samples will be routinely collected or measurements routinely made at on-site and site boundary or off-site locations to determine the extent of environmental discharges during remediation. Monitoring locations will be chosen commensurate with remediation activities.

The NRC staff has reviewed Section 11.1 in the DP according to the Consolidated Decommissioning Guidance, Volume 1, Section 17.4 (Environmental Monitoring and Control Program). Although specific implementation details of the ESP are not provided in the DP, the NRC staff has determined that the general program description provided by Mallinckrodt is sufficient for the staff to conclude that the licensee's program will comply with 10 CFR Part 20. A summary of the environmental monitoring and control program is provided below. Note that the results from the staff's evaluation of the Environmental ALARA, Environmental Monitoring, and Effluent Control programs are combined in this finding.

#### 3.10.1 Environmental ALARA Evaluation Program

The project ALARA aim for effluents is 50% of the respective value in 10 CFR 20, Appendix B. The action levels for air and water effluents are based on the levels provided in 10 CFR 20, Appendix B, Tables 2 and 3. The action levels are 0.75 for environmental air, 0.6 for effluent water, and 0.6 for sewage effluent. If exceeded, an investigation will be initiated. The results of the investigation will include identification of appropriate corrective actions.

3.10.2 Effluent Monitoring Program

In the DP, Mallinckrodt states that concentrations of radionuclides in effluents are not expected to increase as a result of decommissioning activities. No effluent air monitoring is anticipated, since no point source of effluent air is expected to exist. However, in the event a decontamination process exhaust ventilation or similar point discharge of potentially radioactive effluent air were employed, its effluent air would be sampled and analyzed for regulated radioactive particulate.

Environmental sampling stations will be provided during demolition or decontamination activities as required by 10 CFR Part 20 to verify there are no adverse impacts to on-site workers and the public. Each environmental sampling station will be equipped with an air sampler. Collection and analysis of the continuous air samples will be performed during demolition or decontamination activities as required by 10 CFR Part 20. The samples will be analyzed for gross alpha and gross beta activity as representatives of the uranium and thorium series. The analytical instruments will be calibrated using standards traceable to NIST.

3.10.3 Effluent Control Program

Section 11.3 of the DP describes the Effluent Control Program. The primary effluent controls used are expected to be dust suppression and erosion control. Mallinckrodt commits to use a variety of available process options to control the concentration of radioactive material in effluents to the environment. Examples of process controls include recycling, leakage reduction, and modification of facilities, operations, and/or procedures. If further reduction in effluent concentration is necessary, available engineering options will be considered. Examples of available engineering options include filtration, adsorption, containment, and storage. Process and engineering options will be implemented unless a review indicates that a substantial reduction in effluent concentration would not result or costs are considered unreasonable. Effluent controls will be described in a written procedure, work instruction, or safety permit.

3.11 Radioactive Waste Management Program

Decommissioning activity will generate three general categories of solid waste: (1) debris of pavement; (2) concrete slabs; and (3) subsurface material. Pavement includes macadam and concrete pavement removed to access subsurface materials. Concrete slabs include wastewater basin slabs and floor slabs from C-T process and support buildings demolished in Phase I. Subsurface materials will include but not be limited to soil, fill, sewer pipe, and building foundations not removed during Phase I. Subsurface foundations and other concrete, wood, or metal materials from buildings and equipment that previously occupied the site may also be encountered during Phase 2. Soil and fill will be “volumetrically” contaminated. It is anticipated that sewer pipe, foundation material, and other non-soil materials will exhibit surface contamination only. In the discussions below, all subsurface material will generally be referred to as “soil”.

All C-T radioactive waste is expected to be Class A waste. Solid wastes are projected to have average concentrations of natural uranium and natural thorium significantly below exempted quantities of source material as defined in 10 CFR 40.13. Table 12-1 from the DP provides Mallinckrodt’s projected volume of radioactive waste to be:

| Waste Type | Volume ($ft^3$) |
|---|---|
| Pavement | 4100 |
| Building slabs | 13000 |
| Subsurface material | 42000 |
| Unreacted C-T Ore | 81500 |
| TOTAL | 140600 |

The unreacted C-T ore buried in 10 burial pits in Plant 6W is being excavated and shipped offsite for disposal under License Amendment 4 which was approved on May 12, 2008 (ML080940414), and therefore, is no longer within the scope of this DP.

The NRC staff has reviewed the licensee's descriptions of the radioactive waste management program in Section 12 of the DP according to the Consolidated Decommissioning Guidance, Volume 1, Section 17.5 (Radioactive Waste Management Program). Based on this review, the NRC staff has determined that Mallinckrodt's programs for the management of radioactive waste generated during decommissioning operations ensure that the waste will be managed in accordance with NRC requirements and in a manner that is protective of the public health and safety. A summary of Mallinckrodt's waste management program is provided below.

### 3.11.1 Solid Radioactive Waste

#### 3.11.1.1 Solid Radioactive Waste Management

Pavement and excavated subsurface materials will be loaded into roll-off containers or dump trucks at the excavation site. Water misting or similar technique will be used as appropriate to control emissions during excavation and loading. Containers or trucks will be covered prior to movement from the excavation area. Loose material generated during excavation will remain in the excavation. Loose material generated during loading will be removed from pavement and the exterior of containers and trucks before they are moved from the excavation area. Surveys will be performed as appropriate to ensure that loose contaminated material is not carried from the excavation area on containers or vehicles.

Mallinckrodt will use decontamination and volume reduction methods to minimize the volume and cost of radioactive waste requiring disposal. Mallinckrodt and its contractor(s) will determine whether decontamination and final survey of individual materials is preferred over excavation and disposal. Mallinckrodt's waste management program is based on the following preferences:

- excavation or demolition and disposal when it is cost-effective;
- decontamination when it is judged to be cost-effective compared to disposal; and
- decontamination or removal of selected contaminated areas of pavement and subsurface material to reduce the average mass concentration of radioactivity in remaining material below release limits, and therefore minimize the cost of disposal.

Soils and other materials that are not loaded directly into transport containers at the excavation site will be moved by truck or container to a Materials Management Area (MMA). At either the excavation site or the MMA, radioactivity monitoring will be used to segregate solid wastes generated during decommissioning into five categories, depending upon their radioactivity and chemical content;

- non-impacted material,
- soils and materials that are < DCGL for soil and can be returned into an excavation on-site,
- soils and materials that contain unimportant quantities of radioactive material and can be managed by NRC-authorized transfer to a state-regulated disposal facility,
- soils and materials that must be managed at a NRC-licensed disposal facility, and
- soils and materials that contain above-background radioactivity and listed or characteristic hazardous wastes and must be managed as mixed waste.

Soils and other waste materials generated during decontamination and remediation may be temporarily stored at the MMA for sampling and analysis, to accumulate sufficient quantities for economical shipment and disposal, or to coordinate shipments between the carrier and the disposal site. Soils and materials will be stored in covered containers or in piles. If needed to control dust or erosion by wind or rain, covers, surface coatings, or functionally similar techniques will be used. Storm water run-on and run-off controls and monitoring will be used as appropriate. Active controls will include water misting or similarly effective dust control methods as necessary to control release of airborne dust during the material handling operations.

Wastes will be packaged, placarded and/or labeled, and transported in accordance with the requirements of the disposal site and applicable state and federal waste transportation regulations. Wastes will be transported to the disposal facility by rail or truck, depending upon disposal site receiving facilities, equipment availability, cost, and other factors as appropriate. The decommissioning contractor personnel will load C-T radioactive wastes that will be shipped in containers or trucks into transport containers in the MMA.

C-T radioactive wastes that will be shipped by rail gondola cars will be handled differently. To the extent practical, the existing FUSRAP rail car loading facility will be used. This facility was constructed specifically to load contaminated soil and debris into rail gondola cars. Soils will be loaded into containers or trucks at the excavation site or at the MMA and be taken to the FUSRAP soils management area. Contractor personnel, working under agreement with Mallinckrodt, will load the wastes into rail gondola cars. Contractor personnel will perform the work using their health and safety procedures and protocols. In the event that the FUSRAP facility is not available, Mallinckrodt's contractor will load C-T waste into rail gondola cars at a controlled location at the facility and in accordance with the health and safety requirements of the DP.

3.11.1.2 Solid Radioactive Waste Disposition

Mallinckrodt will dispose of contaminated materials by transfer to a licensed disposal facility, by transfer to a disposal facility authorized to receive an unimportant quantity of source material, or may be sorted or decontaminated, surveyed, and released under criteria specified in Section 14 of the DP.

Non-impacted material, confirmed by radiation survey to be indistinguishable from natural background radioactivity, may be released without restriction. In Section 12.1.6 of the DP Mallinckrodt states that before releasing such unaffected, or non-contaminated material, a statistical survey will be developed for that application to demonstrate that contained radioactivity is indistinguishable from background.

Equipment with surficial contamination that is generated during decommissioning which contains less regulated radioactivity than the criterion for unrestricted release specified in

NRC Regulatory Guide 1.86 or in NRC Policy and Guidance Directive FC 83-23, may be released without restriction. Before unrestricted release, that equipment or material would be subjected to a radiation survey.

Soil, debris, and or other material generated during decommissioning whose radioactivity concentration is less than the DCGL may be used for backfill in on-site excavations deeper than 4 ft below grade or would be disposed, up to unimportant quantity as defined in 10CFR 40.13(a), in a off-site facility subject to NRC release and State acceptance.

Waste material whose radioactivity concentration is greater than the DCGL, and less than unimportant quantity of source material, as defined in 10 CFR 40.13, will be disposed in accordance with a NRC-authorized transfer to a disposal facility, subject to approval from the cognizant state regulatory agency (ies), in which the disposal facility is located. Waste Control Specialists in Texas or U.S. Ecology in Idaho, are examples of facilities for the disposal of these materials.

If waste material contains greater than an unimportant quantity of source material, i.e., concentration, of source material as defined in 10 CFR 40.13 it will be disposed at an NRC-regulated disposal facility authorized by radioactive materials license to receive it. Segregation from other material will be maintained.

3.11.2 Liquid Radioactive Waste

Phase 2 operations will not involve use of significant quantities of liquid chemicals requiring treatment and/or disposal. Minimum use of water is anticipated for dust control during soil remediation and demolition of paved surfaces. No free water will be generated by dust control activity.

Soil management and housekeeping activities will be designed to minimize the exposure of contaminated soils to storm-water. However, storm-water from active remediation areas, decontamination areas, and the MMA may contain contaminated soil particles. During remediation, storm-water will be contained, collected, and stored in temporary, dedicated above-ground tanks located in the MMA. Collected water will be used for dust control or be filtered or otherwise treated prior to discharge to the plant sewer system in accordance with the facility's wastewater permit. Used filters and treatment sludge, if any, will be solidified and or dewatered and managed as a solid radioactive waste.

In Section 12.2 of the DP, Mallinckrodt states that water removed from excavations will be managed in a manner similar to decontamination water and storm-water runoff. In the event water were to accumulate in an excavation cavity and impede remediation or radiation survey, Mallinckrodt would implement its water management plan to manage it in conformance with:

- 10 CFR Part 20.2003;
- DP Section 12.2, Liquid Radwaste; and
- Mallinckrodt's Metropolitan St. Louis Sewer District Discharge Permit No. 21120596-00.

Water would be pumped from an excavation cavity into holding tanks or a tank on a truck. It would be transported to a water treatment system on-site where it would be filtered, sampled, and analyzed to verify compliance with 10 CFR Part 20, Appendix B, Table 2, column 2

effluent concentration limits and with the St. Louis Sewer District permit before discharge into MSD sewer system.

If filtration were insufficient to assure the water discharged as effluent complies with the 10 CFR Part 20, Appendix B, effluent concentration limit, additional treatment, either by ion exchange or adding flocculant before filtration, would be done to achieve compliance. Similar practice has been used successfully by the FUSRAP contractor on-site. Used filters and treatment sludge, if any, would be managed as solid radioactive waste. As in the case of radioactive solid waste discussed above, any aqueous radioactive waste generated during decommissioning is expected to be Class A waste.

### 3.11.3 Mixed Waste

Characterization efforts performed to date have not identified any mixed wastes in the soil or other materials to be remediated during decommissioning. Mallinckrodt does not anticipate that mixed waste will be generated by decommissioning efforts. In the event mixed waste is identified during remediation activities, Mallinckrodt will characterize the wastes, identify a disposal method, assess the effect on the schedule, assess related disposal costs, modify handling procedures as needed, and will notify the NRC. Mallinckrodt has a Resource Conservation and Recover Act (RCRA) Part B permit authorizing on-site storage of hazardous and mixed waste. Other than the presence of hazardous chemicals, storage in Mallinckrodt's hazardous waste storage facility, and the labeling and transportation requirements of RCRA and state hazardous waste agencies, mixed wastes will have the same radioactive character and will be managed as solid radioactive wastes described above.

## 3.12 Quality Assurance

The NRC staff has reviewed the QAP described in Section 13 of the DP according to the Consolidated Decommissioning Guidance, Volume 1, Section 17.6 (Quality Assurance Program). Based on this review, the NRC staff has determined that Mallinckrodt's QAP is sufficient to ensure that information submitted to support the decommissioning of its facility should be of sufficient quality to allow the staff to determine if the licensee's planned decommissioning activities can be conducted in accordance with NRC requirements. (Note that this finding incorporates the results of the staff's assessment of the entire QAP.)

### 3.12.1 Organization

The C-T decommissioning organizational structure will consist of a management team from Mallinckrodt and the decommissioning contractor. The Mallinckrodt C-T PM will provide overall direction for the C-T Decommissioning Project. While Mallinckrodt will be responsible for ensuring that the NRC requirements are met, Mallinckrodt intends to contract services to perform decommissioning activities.

The contractor will implement the radiological, occupational, and environmental safety programs and the procedures to implement the program requirements. The contractor will also provide an independent QAP, and provide and manage a trained, experienced labor force to perform the decommissioning activities. The contractor's Project Manager will provide day-to-day direction for the C-T Decommissioning Project, but will report directly to the Mallinckrodt PM.

3.12.2 Quality Assurance Program

Section 13.2 of the DP provides a description of the QAP. Mallinckrodt has committed to perform decommissioning activities in a manner to ensure the results are accurate and that uncertainties have been adequately considered. Mallinckrodt's QAP will apply to all stages of decommissioning through the final survey, validation of the data, and the interpretation of the results to verify that this has occurred. The QAP contains the following essential elements:

- The C-T Decommissioning PM has the overall responsibility for ensuring that the QAP is implemented and maintained;
- All employees of the C-T Decommissioning Project and its contractors are responsible for assuring the quality of the work that they perform and for compliance with the requirements of the QAP;
- Supporting Quality Implementing Procedures will provide step-by-step details for complying with the QAP;
- Written procedures will be reviewed and approved by the Mallinckrodt project manager; and
- Management reviews and self assessments will be used to verify adequate implementation of the QAP.

3.12.3 Document Control

Documents that generate materials or data essential to the quality of decommissioning will be controlled to assure that they are current, correct, are properly evaluated and audited, cite validation back-ups, and are stored and available for inspection or use in generating final project license termination materials.

Documents that specify quality-related requirements and instructions will be identified, reviewed, approved, issued, distributed, and maintained as controlled documents in accordance with written procedures. A listing of the types of documents to be maintained as controlled documents is contained in a Controlled Document List.

Changes to controlled documents will be reviewed and approved by the same organization that reviewed and approved the documents originally, or by other designated, qualified persons. Disposition of a superseded or modified document is controlled in accordance with written procedure. A master list of controlled documents is maintained to identify the current revision number of instructions, procedures, specifications, and drawings important to quality. The list is distributed periodically to those individuals or organizations responsible for maintaining the applicable controlled documents, to prevent the use of outdated or obsolete documents.

Appropriate controlled documents are available in the work area before initiation of and during the performance of activities affecting quality. Changes or revisions to controlled documents are verbally communicated to affected individuals and a required reading program assures awareness of the change.

3.12.4 Control of Measuring and Test Equipment

In Section 13.4 of the DP, Mallinckrodt states that Measuring equipment will be maintained, calibrated, and tested according to Regulatory Guides 4.15 and 4.16 recommendations.

### 3.12.5 Corrective Action

Section 13.5 of the DP describes Mallinckrodt's Corrective Action Program. Conditions adverse to the quality requirements of decommissioning are those conditions that if uncorrected, could violate safety and environmental regulations, and/or license commitments. Non-conformance shall be identified promptly and corrected as soon as practical. Corrective action shall be commensurate with the seriousness of the condition being corrected.

### 3.12.6 Quality Assurance Records

Section 13.6 of the DP describes Mallinckrodt's program for handling decommissioning data. Data will be recorded and documented in a data management system. Entries will include the location of the survey or sampling point on the appropriate building grid. Data management personnel will also ensure that chain-of-custody and data management procedures are followed for decommissioning-related samples. The decommissioning contractor's procedures for proper handling, shipping and storage of samples will be used.

Both direct measurements and analytical results will be documented. The results for each survey measurement or sample and its grid block location, will be listed in tabular form (i.e., result versus sample or survey location).

Data will be recorded in an orderly and verifiable way and reviewed for accuracy and consistency. Each element of the decommissioning process that is important to quality of outcome, from training personnel to calculating and interpreting the data, shall be documented in a way that lends itself to audit. Records of training to demonstrate qualification will also be maintained.

### 3.12.7 Audits and Surveillances

In Section 13.7 of the DP, Mallinckrodt commits to perform audits and surveillances of decommissioning activities. Periodic audits will be performed to verify that decommissioning activities comply with established procedures and other aspects of this QA Plan and to evaluate the overall effectiveness of the QAP. Mallinckrodt and Contractor quality assurance personnel will verify that qualified personnel are used to conduct audits to ensure that the applicable procedures are being properly implemented. The audits will be conducted on at least a semi-annual basis, in accordance with written guidelines or checklists. Health and safety personnel will also conduct semiannual audits in their area of concern or have them performed by qualified personnel. External program audits may be used at the discretion of either Mallinckrodt or contractor management. Audit results will be reported to both Mallinckrodt and contractor management in writing; and actions to resolve identified deficiencies will be tracked and appropriately documented.

## 3.13 Facility Radiation Surveys

Section 14 of the DP describes the facility radiation surveys that have been, or will be conducted to support decommissioning activities at the Mallinckrodt site. These surveys include characterization surveys, remedial action support surveys, and the FSS. The following sections of this SER describe Mallinckrodt's facility radiation surveys.

3.13.1 Release Criteria

Release criteria (DCGL values) have been determined for each medium for each residual radionuclide of interest regulated under the NRC license. These criteria do not apply to other radioactive material, such as background radioactivity, for example, or to unregulated radionuclides such as K-40. The following release criteria will be used at the Mallinckrodt site:

**Soil Release Criterion**

| Radionuclide Group | Composite Dose Factor (mrem/yr)/(pCi/g) | DCGLw (pCi/g) |
|---|---|---|
| Th series | 1.05 | 23.9 |
| Natural Uranium | 0.0347 | 721. |
| 6 Th230 + Ra226 + Pb210 | 0.852 | 29.4 |

Composite Dose Factor and DCGLw Derived Separately.
Dose factor and DCGLw of the thorium series is referenced to Th232.
Dose factor and DCGLw of natural uranium is referenced to U238.
Dose factor and DCGLw of Th230, Ra226, and Pb210 is referenced to Ra226.

**Pavement Release Criterion**

| Radioactivity on Pavement Surface Producing 20 mrem/yr | | | |
|---|---|---|---|
| Radionuclide | Dose Factor | Areal Density Equal to 20 mrem/yr | |
| | (mrem/yr)/(pCi/g) | (pCi/100 sq cm) | (dpm/100 sq cm) |
| U-238 | 8.57E-04 | 1.05E+06 | 2.33E+06 |
| U-234 | 7.02E-05 | 1.28E+07 | 2.85E+07 |
| U-235+DI | 2.16E-02 | 4.17E+04 | 9.26E+04 |
| Th-230 | 1.51E-04 | 5.94E+06 | 1.32E+07 |
| Ra-226 | 4.54E-02 | 1.98E+04 | 4.41E+04 |
| Pb-210 | 1.28E-03 | 7.04E+05 | 1.56E+06 |
| Th-232 | 2.37E-03 | 3.80E+05 | 8.43E+05 |
| Ra-228 | 2.98E-02 | 3.02E+04 | 6.70E+04 |
| Th-228 | 3.20E-02 | 2.82E+04 | 6.25E+04 |
| U nat [b,c] | 1.91E-03 | 4.71E+05 | 1.05E+06 |
| $Th^{230}$+$Ra^{226}$+$Pb^{210}$ [d] | 4.67E-02 | 1.93E+04 | 4.28E+04 |
| Th series [a] | 6.42E-02 | 1.40E+04 | 3.11E+04 |

A Th232 series is the limit for Th232 with all its progeny nuclides present in equilibrium concentration (i.e., radioactivity concentration of each equal to the Th232 concentration). Because Th232 progeny grows in to equilibrium within about 30 years, and because the C-T facilities have existed for nearly that long, Th232 progeny can be expected to be near equilibrium.

B U nat is the limit for U238 with U234 , and their short-lived progeny present in

equilibrium and the U235 series is present in equilibrium in the proportion occurring in natural uranium.

C Radioactivity ratio of U235 -to- U238 = 0.0455 in natural uranium.

D Th230 series includes Th230, Ra226, Pb210, and their short-lived progeny and is referenced to Ra226 radioactivity concentration.

**Surface Contamination Limits**

Maximum Acceptable Surface Radioactivity on Items to be Released for Removal from a Restricted Area Without Restriction on Use

| Nuclides | Average ($\alpha$/min·100 cm$^2$) | Maximum ($\alpha$/min·100 cm$^2$) | Removable ($\alpha$/min·100 cm$^2$) |
|---|---|---|---|
| U + Th mix in Plant 5 | 2800 | 8400 | 600 |

A As used in this table, dpm α means the rate of emission of alpha rays determined by correcting instrument counts per minute for background, efficiency, and geometric factors.

B Measurements of average contaminant should not be averaged over more than 1 square meter. For an object of lesser surface area, the average should be derived for each such object.

C The maximum contamination level applies to an area of not more than 100 cm$^2$.

D The amount of removable radioactive material per 100 cm$^2$ of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

The NRC staff has reviewed the release criteria information in Sections 5 and 14 of the DP in accordance with the Consolidated Decommissioning Guidance, Volume 2, Section 4.1 (Release Criteria). Based on this review, the NRC staff has determined that Mallinckrodt has adequately summarized the DCGL(s) and area factors used for survey design and for demonstrating compliance with the radiological criteria for license termination.

3.13.2 Characterization Surveys

An extensive radiation survey designed to characterize the radiological status of the site was conducted prior to the start of Phase 1 decommissioning activities. Characterization survey results of interest in the Phase 2 Plan are those related to surfaces of pavement, building floor slabs, and subsurface materials. The measurements of primary importance for pavement and building slabs were direct beta/gamma measurements using large-area detectors in both scan and static mode. The measurements of primary interest for subsurface materials were laboratory analyses of key radionuclides in samples collected from boreholes.

Characterization survey measurements may also be used as final survey measurements for a particular survey unit. Where characterization survey data are insufficient in number to serve as the entire data set for a particular survey unit, those data may be supplemented, where appropriate, by additional FSS measurements using a statistically based sampling design.

The NRC staff has reviewed the characterization survey information in Section 14.2 of the DP in accordance with the Consolidated Decommissioning Guidance, Volume 2, Section 4.2 (Characterization Surveys). This review has determined that the radiological characterization of the site, area, or building is adequate to permit planning for a remediation that will be effective and will not endanger the remediation workers, to demonstrate that it is unlikely that

significant quantities of residual radioactivity has not gone undetected, and to provide information that will be used to design the FSS.

3.13.3 Remedial Action Support Surveys

Remedial action support surveys are designed to guide and monitor remedial actions. Remedial action support surveys will be designed to be used as elements of the FSS where practical and where satisfaction of all FSS requirements is achieved. In serving as elements in the FSS, remedial action support measurements may comprise the entire data set for a particular survey unit. Where remedial action survey data are insufficient in number to serve as the entire data set for a particular survey unit, those data may be supplemented, where appropriate, by additional FSS measurements using a statistically based sampling design. Where cleanup is necessary, a survey technician will work actively with the decontamination worker or excavator operator to guide decontamination or excavation to decide when a location is decontaminated to meet the decommissioning goal.

The NRC staff has reviewed the remedial action support survey information in Section 14.3 of the DP in accordance with the Consolidated Decommissioning Guidance, Volume 2, Section 4.2 (Remedial Action Support Surveys). This review has determined that Mallinckrodt has designed the surveys to assist in determining when remedial actions have been successful and the FSS may commence.

3.13.4 Final Status Survey Design

Mallinckrodt has committed to conducting a FSS consistent with the approach presented in MARSSIM, to the extent possible. Section 14.4 of the DP includes a description of the FSS instrumentation, radionuclide concentration background values, survey methodology, and quality assurance / quality control (QA/QC).

The NRC staff has reviewed the FSS design information in Section 14.4 of the DP according the Consolidated Decommissioning Guidance, Volume 2, Section 4.4 (Final Status Survey Design). Based on this review, the NRC staff has determined that Mallinckrodt's FSS design is adequate to demonstrate compliance with radiological criteria for license termination. A summary of the major components of the survey design are presented in Sections 3.3.4.1 through 3.3.4.4 below.

3.13.4.1 Instrumentation

A FSS will consist of scanning, direct stationary surveying, down-hole in situ measurement, and or laboratory analysis of subsurface material samples. Therefore, scanning instruments, direct measuring instruments, and laboratory instruments will be used in conducting the FSS and sample analyses. Section 14.4.1 of the DP provides a list of typical instruments used for the various FSS survey methods. All instruments will be appropriate for the type of survey and the concentration of radioactivity to be measured.

3.13.4.2 Background

The nuclide contaminants of interest are uranium (U-238, U-235 and U-234 and their progeny) and thorium (Th-232 and progeny) are naturally occurring and are detectable. For this reason, estimates of the levels of background radiation are required so that the evaluation of survey results can properly account for the influence of background radiation. As part of the characterization survey, Mallinckrodt conducted background surveys for building slab and pavement surface materials. Background measurements were taken on site or in the immediate vicinity of the site in areas that were not affected by site operations. Table 14-3 from the DP (copied below) shows the background levels which have been determined for asphalt pavement and concrete.

Table 14-3. Background Values of Pavement

| Material | Number of Samples | Average Background (β/min/100 $cm^2$) | Standard Deviation (β /min/100 $cm^2$) |
|---|---|---|---|
| Asphalt | 42 | 254 | 166 |
| Concrete | 70 | 180 | 79 |

In Appendix B of the DP, Mallinckrodt describes its methodology for determining background radionuclide concentrations in subsurface material. Mallinckrodt will use the mean values in Table B-8 from the DP (copied below) as the background radioactivity concentration values for subsurface material.

Table B-8. Estimates of Background Radioactivity Concentrations in Cinder/fill

| Radionuclide | Number of Measurements | Mean Concentration[a] (pCi/g) | Standard Deviation[a] (pCi/g) | 95% confidence limits[a] (pCi/g) |
|---|---|---|---|---|
| U-238 | 130 | 4.4 | 2.3 | 4.1 to 4.9 |
| U-235 | n/a | 0.2 | n/a | n/a |
| Th-230 | 130 | 3.4 | 2.2 | 1.8 to 2.6 |
| Ra-226 | 130 | 2.5 | 2.3 | 1.9 to 2.7 |
| Th-232 | 130 | 1.3 | 0.7 | 1.2 to 1.4 |
| Ra-228 | 129 | 1.2 | 0.6 | 1.2 to 1.4 |
| Th-228 | 129 | 1.3 | 0.8 | 1.2 to 1.5 |

a Derived from the Weibull probability distribution.

The Mean Concentration for U-235 is 0.0455 times U-238; i.e. assumption of natural uranium.

3.13.4.3 Survey Methodology

The FSS will be designed in accordance with MARSSIM, NUREG-1757 Appendix E, and NUREG-1505 to the extent practical. The FSS is designed to provide a high degree of assurance that release criteria are met.

3.13.4.4 Final Status Survey QA/QC

The FSS will be subject to the QAP described in Section 13 of the DP.

3.13.5 Final Status Survey Report

At the conclusion of the FSS, Mallinckrodt will submit FSS Report (FSSR) to the NRC which demonstrates that the C-T process areas meet the radiological criteria for unrestricted release. Section 14.5 of the DP states that the report will include the following information:

- overview of the results of the FSS;
- discussion of any changes made in the FSS from what was proposed in the DP and associated submittals;
- a description of the method by which the number of samples was determined for each survey unit;
- a summary of the parameter values used to determine the number of samples and a justification for them;
- the survey results for each survey unit, including:
  - the number of samples;
  - a figure (map or drawing) depicting the survey unit, the location reference system, start locations for survey units subject to systematic sampling, randomly selected sampling locations for other survey units;
  - sample measurement results;
  - results of statistical evaluation of sample measurements;
  - judgmental and miscellaneous sample data sets reported separately from those samples collected for performing the statistical evaluation;
  - identification of each area of elevated direct radiation detected during scanning that exceeded the investigation level or measurement location(s) in excess of DCGLw; and
  - a statement that the survey unit satisfied the DCGLw and, if any samples exceeded the DCGLw, a statement that the survey unit satisfied the elevated measurement comparison;
- if a survey unit fails, a description of the investigation conducted to ascertain the reason for the failure and a discussion of the impact that the failure has on the conclusion that the facility if ready for final radiological surveys; and
- if a survey unit fails, a discussion of the impact of the cause of failure on other survey unit information.

The NRC staff has reviewed the FSSR information presented in Section 14.5 of the DP according the Consolidated Decommissioning Guidance, Volume 2, Section 4.5. Based on this review, the NRC staff has determined that Mallinckrodt has demonstrated that the licensee's FSSR will contain sufficient information for the NRC to determine whether the radiological criteria for license termination have been met.

3.14 Financial Assurance

Section 15 of the DP provides a cost estimate for the decommissioning activities proposed in the DP. The cost estimate for the remaining decommissioning work is $17,330,728, which includes a 25 percent contingency fee. The existing financial assurance is a letter of credit in the amount of $21,113,000 which is sufficient to complete the proposed Phase 2 decommissioning activities.

## 4. REGULATORY EVALUATION

Mallinckrodt's DP requests that NRC terminate its license in accordance with 10 CFR 20.1402 without accounting for MED-AEC contamination in demonstrating compliance with the dose limits in 20.1402. The NRC staff cannot approve this request without exempting this MED-AEC material from consideration in demonstrating compliance. Although Mallinckrodt has not requested such an exemption, the staff believes that, given the unique circumstances at this site, there is a strong basis for including such an exemption in this licensing action. As described in detail below, the unique circumstances are that, a federal agency, USACE, is responsible for remediating the MED-AEC material and has committed to remediate that material to the standards in 10 CFR 20.1402 (NRC, 2001). This particular circumstance provides the staff with reasonable assurance that health and safety and the environment will be protected because the material will be controlled by Mallinckrodt until USACE completes remediation to NRC standards.

The radiological criteria for license termination are set forth in 10 CFR Part 20, Subpart E. Mallinckrodt is proposing to terminate its NRC license in accordance with 10 CFR 20.1402, Radiological Criteria for Unrestricted Use, which states:

> A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a TEDE to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). Determination of the levels which are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal.

The term "residual radioactivity", as used in 10 CFR 20.1402, is defined in 10 CFR 20.1003 as:

> Residual radioactivity means radioactivity in structures, materials, soils, groundwater, and other media at a site resulting from activities under the licensee's control. This includes radioactivity from all licensed and unlicensed sources used by the licensee, but excludes background radiation. It also includes radioactive materials remaining at the site as a result of routine or accidental releases of radioactive material at the site and previous burials at the site, even if those burials were made in accordance with the provisions of 10 CFR part 20.

Under this definition, MED/AEC contamination is considered to be residual radioactivity and, unless exempted, must therefore be included in Mallinckrodt's determination that the site meets 25 mrem/yr unrestricted release criteria of 10 CFR 20.1402. The NRC is granting an exemption which permits the staff to terminate Mallinckrodt's license after Mallinckrodt has completed decommissioning of the C-T process areas and demonstrates that the dose criteria of 10 CFR 20.1402, are met without considering the dose contribution from unlicensed MED/AEC contamination remaining on site.

The basis for granting the exemption is: (1) Mallinckrodt will meet 25 mrem/yr unrestricted release criteria for C-T process areas; and (2) unlicensed MED/AEC material is being remediated to NRC unrestricted release standards of 25 mrem/yr by USACE.

Basis for Exemption

The Mallinckrodt site is a 43 acre site subdivided into ten areas called Plants. The former C-T process areas included 21 support buildings on approximately 4.2 acres, primarily located within Plant 5, but also in portions of Plants 1, 2, 6, 7, and 8. USACE is responsible for remediating the remainder of the site under FUSRAP.

To date, USACE has completed remediation of Plants 1, 2, 3, 8, 9, 10 and 11 in accordance with the St. Louis Downtown Site (SLDS) Record of Decision (ROD). Under the ROD, USACE is remediating only accessible soil. Accessible soil is soil that is not located beneath buildings or other permanent structures (e.g., active rail lines, roadways, the levee, sewers, etc.). The inaccessible material will be addressed at a later time under another ROD.

Mallinckrodt completed remediation activities in Plants 1, 2 and 8 during Phase 1. Mallinckrodt's Phase 2 DP addresses remediation activities within Plant 5 and portions of Plants 6, and 7. Mallinckrodt and USACE have reached an agreement regarding delineation of responsibility for remediating Plant 6, but have not yet agreed on the delineation of responsibility for Plant 7. After Mallinckrodt and USACE reach agreement on the delineation of responsibility for Plant 7, remediation of C-T process areas and MED-AEC process areas can be conducted independently. It is expected that Mallinckrodt will complete remediation in Plant 5 and the C-T process areas of Plants 6 and 7 before USACE completes remediation in the remainder of the site.

Mallinckrodt is requesting NRC to terminate its license after it completes decommissioning of C-T process areas on site. Without the exemption, the staff would be unable to approve Mallinckrodt's DP and terminate NRC License STB-401 because areas of the site contain MED-AEC material which will not be remediated by USACE by the time Mallinckrodt completes decommissioning.

Terminating Mallinckrodt's license without accounting for MED-AEC residual radioactivity does not reduce Mallinckrodt's remediation responsibilities at the site, nor increase the potential dose to workers at the end of Mallinckrodt's remediation activities. In the DP, Mallinckrodt commits to remediate the C-T process areas to meet the NRC's unrestricted release criteria of 10 CFR 20.1402. Therefore, with or without the exemption, Mallinckrodt is required to meet the same cleanup criteria for the C-T process areas.

The cleanup criteria used by USACE at the Mallinckrodt site are provided in the existing ROD for accessible MED-AEC material. These criteria were developed to meet several objectives including the requirements of 40 CFR 192 and the NRC's unrestricted release criteria of 10 CFR 20.1402. Specifically, the ROD states that 10 CFR Part 20, Subpart E, standards are relevant and appropriate to any FUSRAP materials similar to licensable materials under the Atomic Energy Act.

Mallinckrodt and USACE have selected clean-up criteria such that for an industrial worker, the unrestricted release dose criterion of 10 CFR Part 20.1402, are met. The NRC staff finds that the 25 mrem/yr dose criterion does not have to be apportioned between C-T and MED-AEC areas. Workers on-site engaged in non-NRC licensed activities will not receive more than 25 mrem/yr during or after completion of decommissioning activities.

Without an exemption, the staff could not terminate Mallinckrodt's STB-401license until USACE completes remediation of MED-AEC material exceeding USACE's cleanup criteria. However, if USACE and Mallinckrodt independently demonstrate that the MED-AEC and C-T

process areas, respectively, meet NRC's unrestricted release criteria, then the entire site should meet NRC's unrestricted release criteria at completion of site decommissioning activities.

The staff concludes that it is reasonable to terminate License STB-401 after Mallinckrodt completes decommissioning activities in the C-T process areas and demonstrates that the C-T process areas at the site meet NRC's unrestricted release criteria. NRC staff would not be able to make this conclusion absent a commitment by a Federal entity with concurrent cleanup responsibility and authority for remediation of the site.

Additional Consideration

One possible consideration associated with terminating Mallinckrodt's STB-401 license prior to completion of all C-T and MED-AEC remediation activities, is the potential for the public to be exposed to residual radioactive material remaining on site. Three potential exposure scenarios caused by direct contact with residual radioactive material are: (1) public dose during C-T and MED-AEC remediation activities; (2) public dose after completion of C-T decommissioning activities, but during MED-AEC remediation activities; and (3) public dose after completion of C-T and MED-AEC remediation activities from inaccessible material remaining on-site.

During C-T and MED-AEC decommissioning activities, Mallinckrodt and USACE are responsible for controlling access to contaminated areas of the site. Therefore, only remediation workers should have potential contact with contaminated material when remediation activities are occurring on-site.

Mallinckrodt states in the DP that it intends to continue its non-licensed operations after completion of C-T decommissioning activities. Mallinckrodt limits access to its facilities to employees, subcontracting construction workers, and authorized visitors and maintains 24-hour security at the property. The general public does not have immediate access to its facilities. Once USACE has completed decommissioning activities in accordance with the existing ROD for accessible material, only inaccessible MED-AEC residual radioactive material above the clean-up criteria will remain on-site. Since the contaminated material is inaccessible, Mallinckrodt employees, subcontracting construction workers, and authorized visitors can not come in direct contact with the material and thus cannot receive a significant dose from it.

In conclusion, the NRC staff has determined that it is reasonable to exempt Mallinckrodt from considering unlicensed MED-AEC residual radioactive material in its demonstration that the site meets the unrestricted release dose requirement of 10 CFR 20.1402. This exemption will not result in a reduction of Mallinckrodt's decommissioning responsibilities, nor an increase in potential dose to the public or workers upon completion of decommissioning activities at the site.

## 5. STATE CONSULTATION

The State of Missouri provided technical comments on the Phase 2 DP to the NRC on November 3, 2003 (ML033220283) and March 6, 2009 (ML090790209). The States comments were discussed at a public meeting on April 24, 2009. The States comments were adequately addressed in the final version of the DP. In addition, NRC provided draft copies of the EA and this SER to the State for review and comment (ML092030390). The State provided comments on May 6, 2010 (ML101370123). The Final version of the EA and

SER addressed the States comments as indicated in a letter dated May 24, 2010 (ML101370174).

## 6. EPA CONSULTATION

On October 9, 2002, the NRC and EPA entered into a Memorandum of Understanding (MOU) on "Consultation and Finality on Decommissioning and Decontamination of Contaminated Sites". In accordance with the MOU, for decommissioning sites which trigger the criteria in the MOU, NRC is required to consult with EPA in the decommissioning process. On June 22, 2009 (ML091460665), NRC informed EPA that the soil DCGLs for the Mallinckrodt site exceeded the trigger criteria contained in the MOU. EPA responded to NRC's consultation letter on September 9, 2009 (ML092740369). NRC responded to EPA's letter on October 21, 2009 (ML092810106), concluding that the post-remediation dose will meet NRC's dose criterion in 10 CFR 20.1402.

## 7. CONCLUSIONS

Based on the considerations discussed above, NRC concludes that; (1) there is reasonable assurance that the health and safety of the public will not be endangered by the proposed decommissioning activities, and (2) the proposed decommissioning activities will be conducted in accordance with NRC regulations.

## 8. REFERENCES

Mallinckrodt Inc., Mallinckrodt C-T Decommissioning Project, C-T Phase II Decommissioning Plan, Revision 2, October 14, 2008.

Memorandum of Understanding (MOU) on "Consultation and Finality on Decommissioning and Decontamination of Contaminated Sites," October 9, 2002.

NRC, "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," August, 1987.

NRC, "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)", NUREG-1575, EPA 402-R-97-016, December 1997.

NRC, "Memorandum of Understanding Between the U.S. Nuclear Regulatory Commission and the U.S. Army Corps of Engineers for Coordination of Cleanup & Decommissioning of the Formerly Utilized Sites Remedial Action Program (FUSRAP) Sites With NRC-Licensed Facilities," Federal Register / Vol. 66, No. 134, July 12, 2001.

U.S Army Corps of Engineers, Record of Decision for the St. Louis Downtown Site, July 1998.